Combustion

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

APRIL 1961

Gas Turbine Co Boiler Heat Balance

Furnace Safeguards

Steam Power Plant Clinic

American Power Conference

Heat energy released by the combustion of fuel generates about 80 per cent of America's electric power. And, during the decade just passed, Combustion Engineering supplied over 40 per cent of the new steam generating capacity added by the nation's electric utility industry.

Because of continuing technological progress, postwar inflationary trends have had little effect on the unit cost of electricity to residential and industrial users. In fact, the average cost per kilowatt-hour the country over is much less today than it was in the thirties. The ever increasing efficiency of converting the heat energy of fuel into electrical energy, as evidenced by the coal consumption rates listed above, is the principal reason why electricity continues to be "America's best buy".

Combustion Engineering, through its development of new and improved boiler designs, has been a major contributor to this advancing technology. These developments have made possible the use of ever higher steam pressures and temperatures and larger turbine capacities. (The capacity of the average turbine powered by C-E Boilers has more than tripled since 1950.)

These and other advances have helped the electric utility industry to counter the effects of inflation. This has been good for everyone – American homes and American industry alike.

Eddystone station of Philadelphia Electric Company. Here, two C-E Sulzer Monotube boilers, each powering a 325-megawatt turbine, went into service in 1960. Both operate in what is called the "supercritical" range. The first is designed to produce steam at record pressures and temperatures – 5,000 pounds per square inch and 1200°F.

COMBUSTION ENGINEERING

C-E

GENERAL OFFICES: Windsor, Conn.
NEW YORK OFFICES: 200 Madison Avenue, New York 16

C-303

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS; PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

Combustion

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

volume 32 number 10 **April 1961**

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Printed in U. S. A.

COVER PHOTO

First use of stainless steel in a condenser within the Duquesne Light Co.'s experience took place at their Elrama Power Plant.

A Gas Turbine CO Boiler Installation; Economic and Thermodynamic Analysis . . . 22

Charles Bultzo

Here is an interesting and fact-packed story of a number of tests run to determine the values and the savings from a combined cycle

Furnace Safeguards Panel . . . 31

Last of three parts in which a panel of experts discuss different problems of different fuels, equipment shut down, inter-plant communications

Steam Power Plant Clinic—Part XXIII . . . 44

Igor J. Karassik

Pumping problems in a power house—variations of NPSH during transient conditions and the need for individual pump by-pass controls are covered

Pneumatic Material Handling System Solves Difficult Flyash Disposal Problem . . . 50

R. G. James

A quick, heavily illustrated story of AEC's Hanford plant's solution of a typical power plant problem

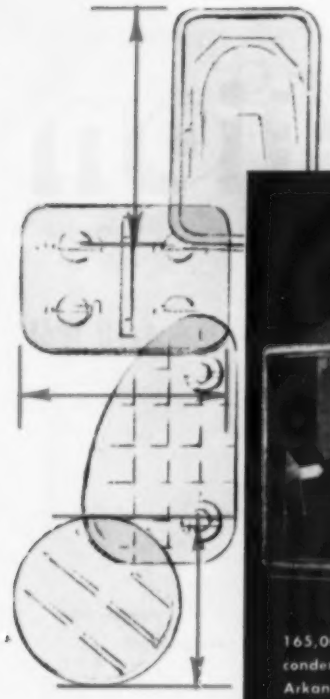
American Power Conference in Review . . . 53

Abstracts From the Technical Press . . . 59

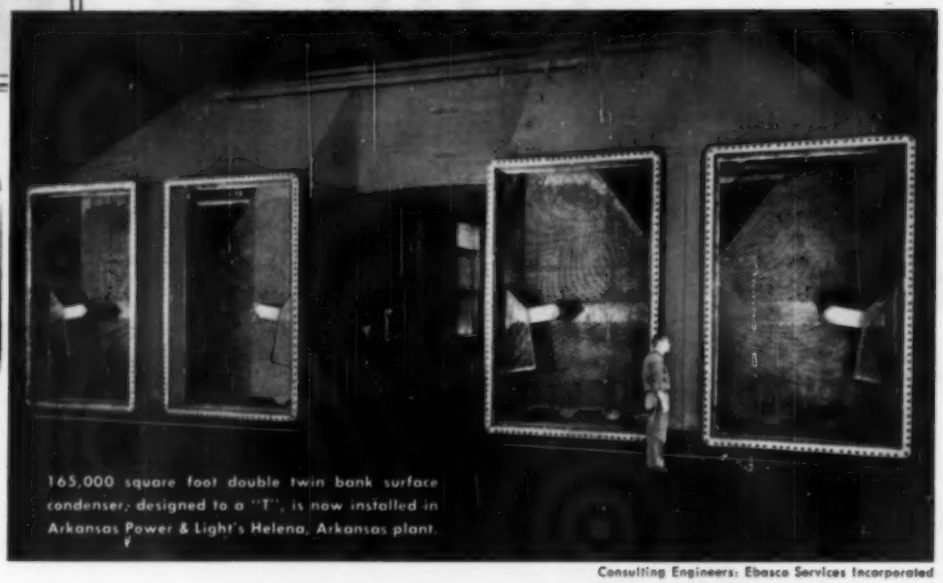
Editorials: On Hard-Head Engineers . . . 21

by James T. Fairman

Advertising Index . . . 64, 65 **Book Reviews . . . 16**



YUBA CONDENSERS
ANY SIZE . . . ANY ARRANGEMENT



165,000 square foot double twin bank surface condenser, designed to a "T", is now installed in Arkansas Power & Light's Helena, Arkansas plant.

Consulting Engineers: Ebasco Services Incorporated

MOST VERSATILE TUBE BANK LAYOUT IN THE INDUSTRY

YUBA SURFACE CONDENSER DESIGN . . . most flexible...any size...any arrangement. Through design advances such as those incorporated in the unit above, Yuba illustrates the concepts you can expect from years of engineering leadership in the power industry.

Yuba's twin-bank tube layout, seen here in a two shell "T" type installation, promotes unobstructed, equally distributed flow. Through Yuba's patented design, the condensate can be deaerated with oxygen content guaranteed to be less than 0.005 cc per liter.

As a design extra, Yuba staggers the tube support plates – reducing harmonics – eliminating vibration. These are some of the reasons why Yuba surface condensers of all sizes have been installed in plants throughout the world. You'll want to know more about the most versatile tube bank layout in the industry – contact Yuba today.

Other Yuba products for steam power plants include feedwater heaters, evaporators, expansion joints, cranes, tanks, structural steel erection, and scores of other items.

YUBA

specialists in power plant equipment

YUBA HEAT TRANSFER DIVISION

YUBA CONSOLIDATED INDUSTRIES, INC.

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'BUFFALO' – MOST COMPLETE LINE OF QUALITY HEATING, VENTILATING AND MAKEUP AIR UNITS

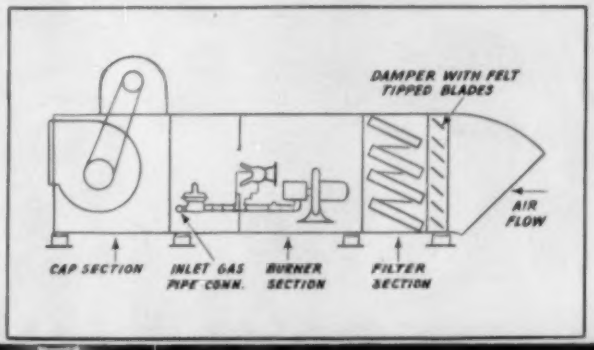
Whatever the air temperature requirements for your boiler room, turbine room or other plant areas, there's a 'Buffalo' Unit to give you permanent satisfaction. All embody the same quality engineering as the broad line of 'Buffalo' Mechanical Draft Fans.

For ventilation, you have 'Buffalo' Centrifugal, Propeller and Axial Flow Fans to choose from, depending on space, pressure and volume requirements. All are proven fans for specific design conditions, and may be used for supplying makeup air or exhausting.

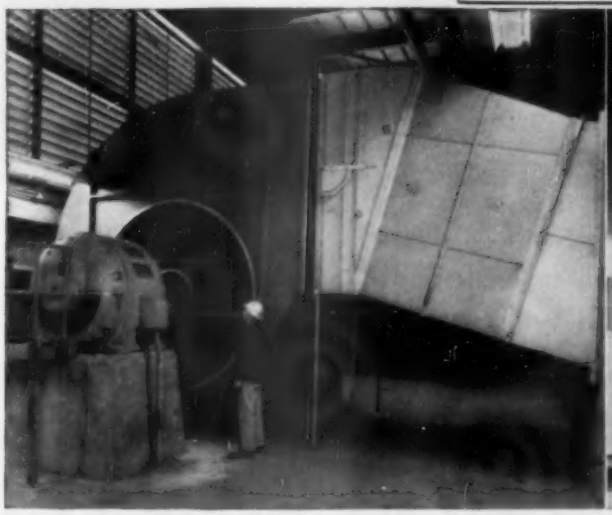
Sky Vent Power Roof Ventilators are efficient, weather-proof packages for economical installation without duct or floor space requirements. Available in 1,000 to 250,000 cfm capacities, and can be arranged with heating coils and dampers for supplying makeup air.

New 'Buffalo' Direct Gas-Fired Makeup Air Units provide fresh, clean, tempered air without increasing boiler load. Units operate at virtually 100% thermal efficiency, with complete safety and freedom from attention. Can be built into Style H Sky Vent units. Also available with centrifugal blower head and accessories such as filters, dampers, etc.

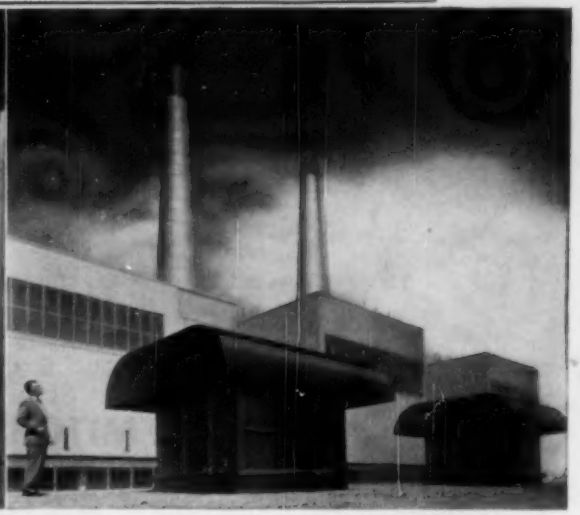
Write us about your heating, ventilating or makeup air problem—we'll give you details and recommendations promptly.



'Buffalo' Direct Gas-Fired Makeup Air Unit



'Buffalo' Type BL Ventilating Fan



'Buffalo' Power Roof Ventilators

BUFFALO FORGE COMPANY
Buffalo, New York
Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

'Buffalo' Air Handling Equipment to move, heat, cool, dehumidify and clean air and other gases.

'Buffalo' Machine Tools to drill, punch, shear, bend, slit, notch and cope for production or plant maintenance.

'Buffalo' Centrifugal Pumps to handle most liquids and slurries under a variety of conditions.

Sawyer Machinery to process sugar cane, coffee and rice. Special processing machinery for chemicals.

Juvenile cowhands, legs bowed and toes turned in, are good for a laugh, since everyone knows that efficiency on the range requires experience. By the same token . . . for full and lasting satisfaction on your next critical-piping job, delegate it directly to specialists . . . Ask us in.

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Philadelphia 46, Pa.

MITCHELL PIPING
SINCE 1899

PIPING FABRICATORS AND CONTRACTORS

This 25' Ljungstrom rotor will contain a total heating surface of 128,000 sq ft. Continuous heat recovery by this unit will boost the temperature of incoming combustion air from 100°F to 585°F. Every 45-50°F thus returned as preheat increases boiler efficiency about 1%.

DOW RECOVERS 425°F WITH LJUNGSTROM® AIR PREHEATER

When Dow Chemical Company's Westside Power House at Midland, Mich., starts up their new 650,000 lb/hr boiler, more than half the waste heat will be *recovered* by a Ljungstrom Air Preheater. Dow's newest Ljungstrom (this is the eighth in their system) was designed to lower stack gas temperature from 700°F to 275°F, thus *recovering 425°F.* As a direct result, company engineers expect at least 10% reduction in fuel costs.

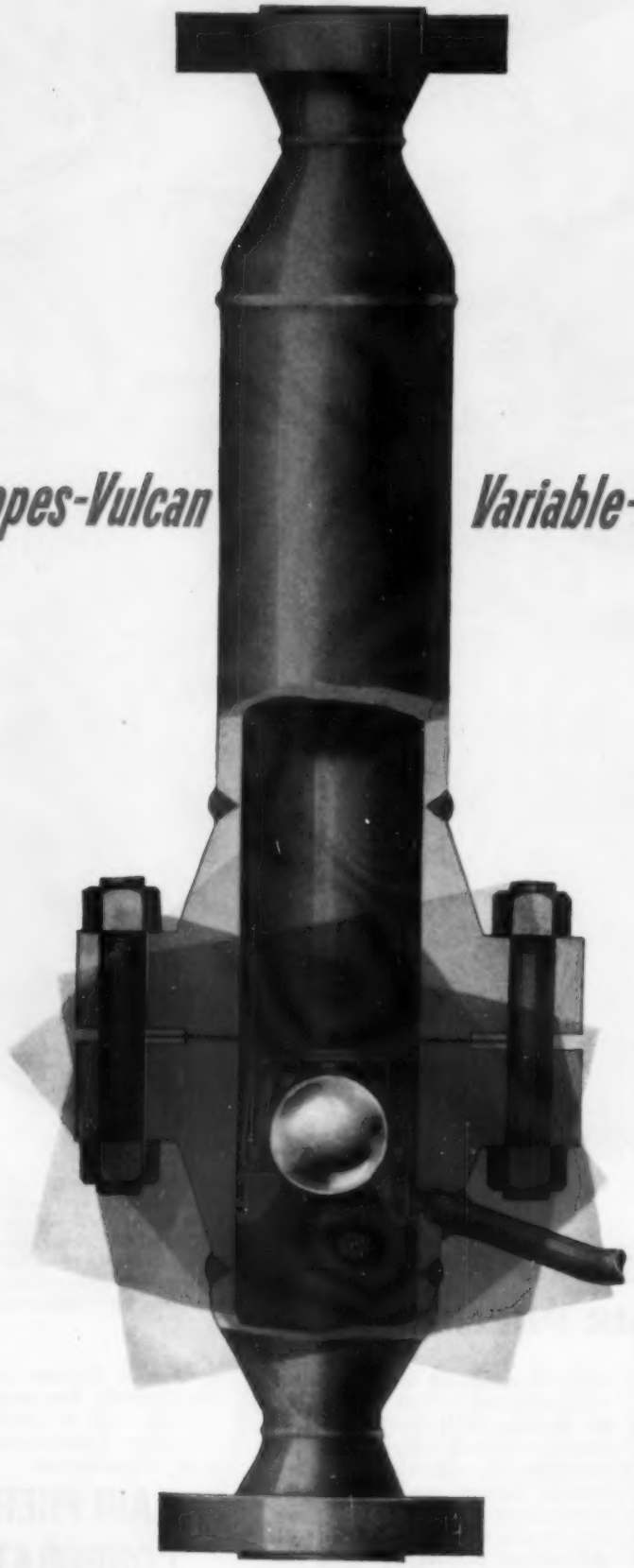
On process stills or boilers—or wherever large volumes of heat are involved—Ljungstrom Air Preheaters improve combustion, make fuel burn more completely. It's possible to save as much as 20% on fuel.

***All* major public utilities** use Ljungstroms; as do many major chemical and petroleum processing companies. Chances are, you, too, could benefit. For additional information, call or write The Air Preheater Corporation, specifying type of application.

THE AIR PREHEATER CORPORATION

60 East 42nd Street, New York 17, N.Y.

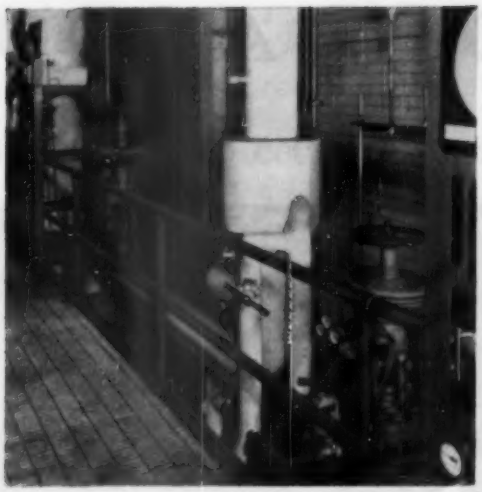
Copes-Vulcan Variable-Orifice desuperheater



This ball makes the difference. Steam pressure lifts a weighted steel ball off its ring seat to a position where it is balanced by steam pressure and flow through the orifice. The ball is held concentric by Inconel springs and rigid guides. This is the only moving part in the Copes-Vulcan Variable-Orifice desuperheater that so effectively controls steam temperature.

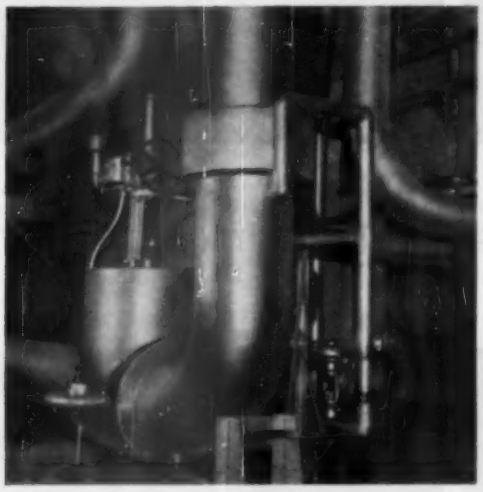
Cooling water enters through an annular orifice surrounding the ring seat at the point of maximum steam velocity. The passage of steam through the annular restriction between ball and seat produces an aspirating effect on the cooling water and entrains it in an area of high turbulence over the full range of flow.

No long run of piping is needed to mix the two fluids. There is no excess water to remove. No atomizing steam is used. There are no glands, stuffing boxes or spray nozzles. Pressure drop remains constant for all flows, and is normally 3 to 4 psig. Write for Bulletin 1037.



The problem: to maintain the temperature of residual fuel oil at 335°-380°F using station steam at 1250 psig and 950°F. Because of the high temperature heating requirements of the fuel, it was necessary to use the station steam supply. To handle this tough assignment a single, combination pressure-reducing and regulating valve, Copes-Vulcan Type CV-D, followed by the Copes-Vulcan Variable-Orifice desuperheater was used. The cooling-water valve is also a Type CV-D. The desuperheater provides steam at the right temperature to control the fuel oil temperature and viscosity exactly. It has been in service over two years with no downtime and no operating problems.

solves knotty problems at two generating plants



The problem: to deliver 420°F steam at from 20,000 to 300,000 pounds per hour and within ± 5°F of the set point. Conventional desuperheating equipment could not be used because of the low superheat (30°F) and low flow conditions. A 12-inch, 300-psig standard Copes-Vulcan Variable-Orifice desuperheater, with outlet expanded to 20-inch pipe size, was the answer. The inlet is connected with the main steam-distribution header carrying steam at 220 psig and 500°F. The cooling-water supply is at 450 psig and 200°F. The specified pressure range is 425 to 475 psig. Cooling-water flow is automatically regulated by a Copes-Vulcan Type CV-D valve operated by a temperature controller in the steam heating supply line. Flow requirements at discharge temperature within ± 5°F have been met consistently though inlet temperatures vary from 520°F to 550°F.

Copes-Vulcan desuperheaters are designed for precise control of reduced steam temperatures under the most difficult operating conditions.

In addition to the Variable-Orifice, two other types are available. *The Carburetor-Type desuperheater* injects cooling water into the system with a spray nozzle. Available in standard 2-inch through 12-inch sizes in 150- through 600-pound pressure standard for cast steel. Larger sizes and higher pressure standards are available on special application. Write for Bulletin 1056.

Steam-Assist desuperheater has negligible permanent pressure loss on loads of 15% to 100% of maximum. This in-line desuperheater normally uses assisting steam only on light loads where control is most difficult. Write for Bulletin 1024-A. Copes-Vulcan Division, Erie 4, Pennsylvania.

Copes-Vulcan Division

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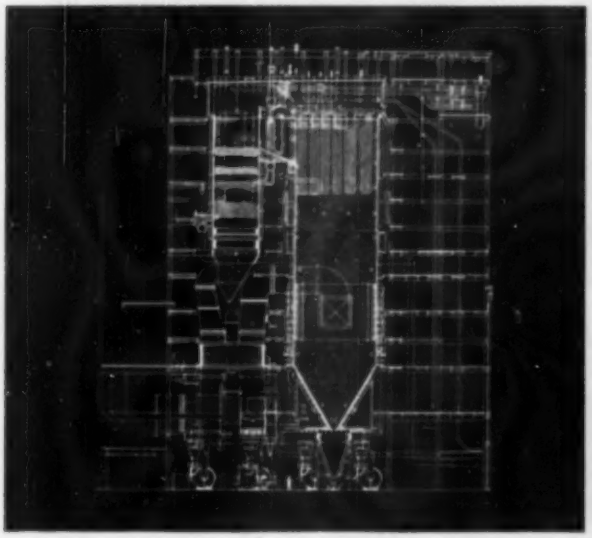
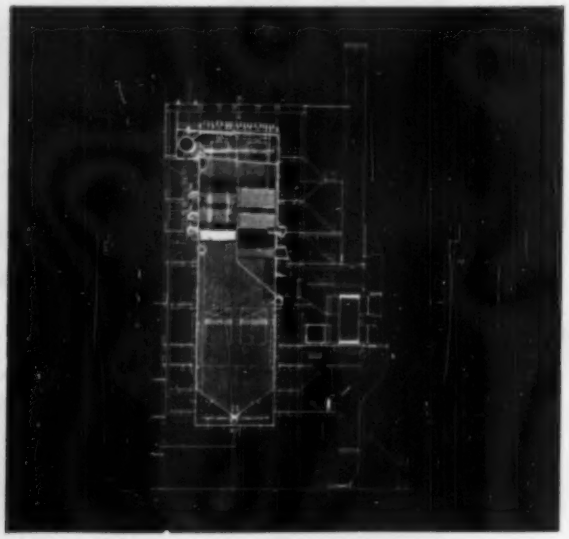
Blaw-Knox designs and manufactures for America's growth industries: METALS: Rolling Mills • Steel Processing Lines • Rolls • Castings • Open Hearth Specialties • PROCESSING: Process Design, Engineering and Plant Construction Services • Process Equipment and Pressure Piping • CONSTRUCTION: Concrete and Bituminous Paving Machines • Concrete Batching Plants and Forms • Gratings • AEROSPACE: Fixed and Steerable Antennas • Radio Telescopes • Towers and Special Structures • POWER: Power Plant Specialties and Valves

COMBUSTION'S ANNUAL

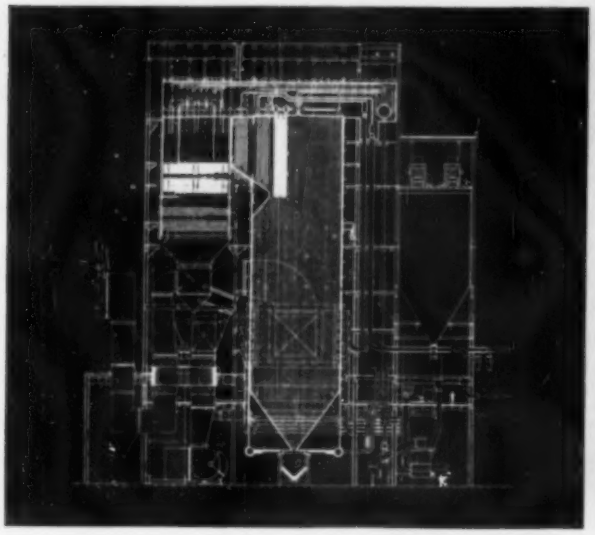
A REPRESENTATIVE CROSS SECTION OF 1960 C-E INSTALLATIONS



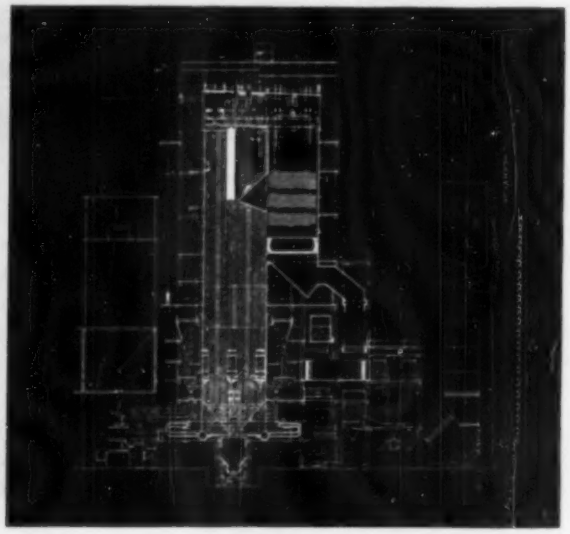
This pulverized coal fired C-E Sulzer Monotube Steam Generator went into service in 1960, at the Eddystone Station of Philadelphia Electric Company. The 325-mw unit is designed to provide steam at 5000 psi with superheat and reheat temperatures of 1200F/1050F/1050F.



This 110-mw unit went into operation at the Ocotillo Steam Electric Station of Arizona Public Service Company. It is a C-E radiant reheat boiler, fired by natural gas and oil, and produces steam at 1925 psi. Superheat and reheat temperatures are 1005F/1005F.



A 500-mw unit was placed in service at the Widows Creek Station of the Tennessee Valley Authority in 1960. It is a C-E Controlled Circulation, radiant reheat boiler, pulverized coal fired, producing steam at 2450 psi. Superheat and reheat temperatures are 1053F/1003F.



This C-E Controlled Circulation, radiant reheat boiler was placed in service at Montrose Steam Electric Station of Kansas City Power & Light Company in 1960. The 156-mw unit, fired by pulverized coal, produces steam at 1925 psi. with superheat and reheat temperatures of 1005F/1005F.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS;

STATISTICAL REPORT

In 1960, the electric utility industry placed in service about 10,800 megawatts of new thermal generating capacity.* C-E's contribution to this total was 4,678 megawatts and included two noteworthy firsts. One, a C-E Controlled Circulation unit is the world's first boiler to serve a 500 megawatt turbine-generator. The other represents the most advanced power plant cycle yet attempted. It is a C-E Sulzer Monotube Steam Generator designed to deliver 1200F steam at a pressure of 5000 psi to a 325 megawatt turbine-generator. Both of these units were placed in commercial operation in 1960.

During the year, the electric utility industry ordered approximately 3,700 megawatts of new boiler capacity from C-E. Over 80% of this total is to be served by C-E Controlled Circulation Boilers. More than 60% of the total capacity ordered is for turbine throttle operation of 2400 psi and above. C-E's 1960 order board shows a total of 5 units with capacities of 300 mw and above, including one 500 mw unit.

*Source, "Electrical World"

THE C-E CONTROLLED CIRCULATION STORY

Total capacity ordered, as of year-end 1960	26,300 mw
Total capacity in service, as of year-end 1960	16,421 mw
Capacity ordered in 1960	3,055 mw
Capacity placed in service in 1960	3,108 mw

THE C-E 2400 PSI STORY

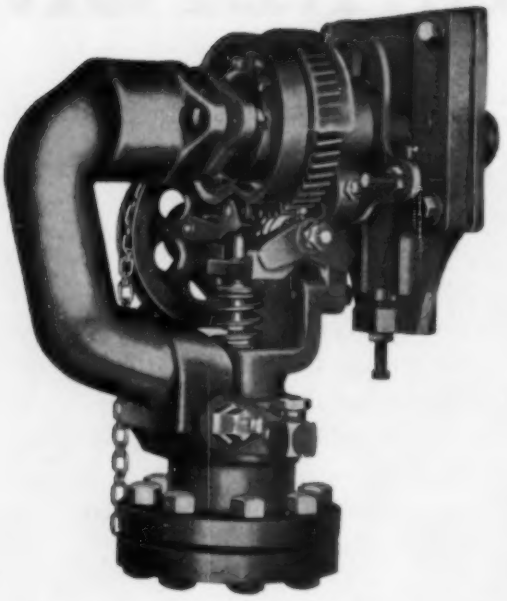
Total capacity ordered, as of year-end 1960	12,185 mw
Total capacity in service, as of year-end 1960	6,093 mw
Capacity ordered in 1960	2,250 mw
Capacity placed in service in 1960	2,266 mw

COMBUSTION **ENGINEERING**

C-307

General Offices: Windsor, Conn. • New York Offices: 200 Madison Avenue, New York 16, N. Y.

PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE



Quick Opening Bayer Soot Blower Valves Assure

- 100% cleaning efficiency
- minimum steam consumption
- superior high temperature resistance

The Bayer Balanced Valved Soot Blower is a single-chain operated design that assures precise sequential operation of the valve and element. *Only* after the start of full steam flow does element rotation commence—a feature which provides positive and efficient cleaning over the entire arc. . .without wasting steam.

The Bayer Soot Blower is simply operated by a pull on the chain which opens the cam-actuated valve. Continued pulling of the chain slowly rotates the element through its cleaning arc, at the end of which the valve automatically closes.

For severe high temperature locations, "super service" elements of Bayer-developed "Chronilloy" are available. Of superior strength, wrap-resistance, and stability, these elements resist the oxidation and chemical action caused by very high temperature gases.

In over fifty years of continuous specialized service, the Bayer company has equipped more than 35,000 boilers with dependable soot blowers. Engineered for long life and low maintenance, Bayer products assure economical and trouble-free operation.

ADVANTAGES OF THE BAYER BALANCED VALVED SOOT BLOWER

- single chain operation
- individual elements adjustable for high pressure service by orifice plate valve
- full steam pressure over entire cleaning arc
- selected gear ratios for optimum rate of element rotation
- minimum pressure drop through valve body
- machined air seal with spring loaded seat
- complete vacuum breaker protection
- precision swivel tube alignment lessens stuffing box packing needs
- load carried on ring type thrust bearings

For further information contact the Bayer representative nearest you. He is an experienced engineer, qualified to service Bayer Soot Blowers.

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The BAYER COMPANY

4030 Chouteau Avenue, St. Louis 10, Missouri

new Yarway Unit Tandem Valve for blow-off service up to 665 WSP . . . gives you the same time-proven dependability of the famous 1500 and 2500 WSP Yarway Unit Tandem design. Streamlined, light in weight, easy to operate, tight sealing, with minimum maintenance.

Ask for free Bulletin B-435, Supplement A

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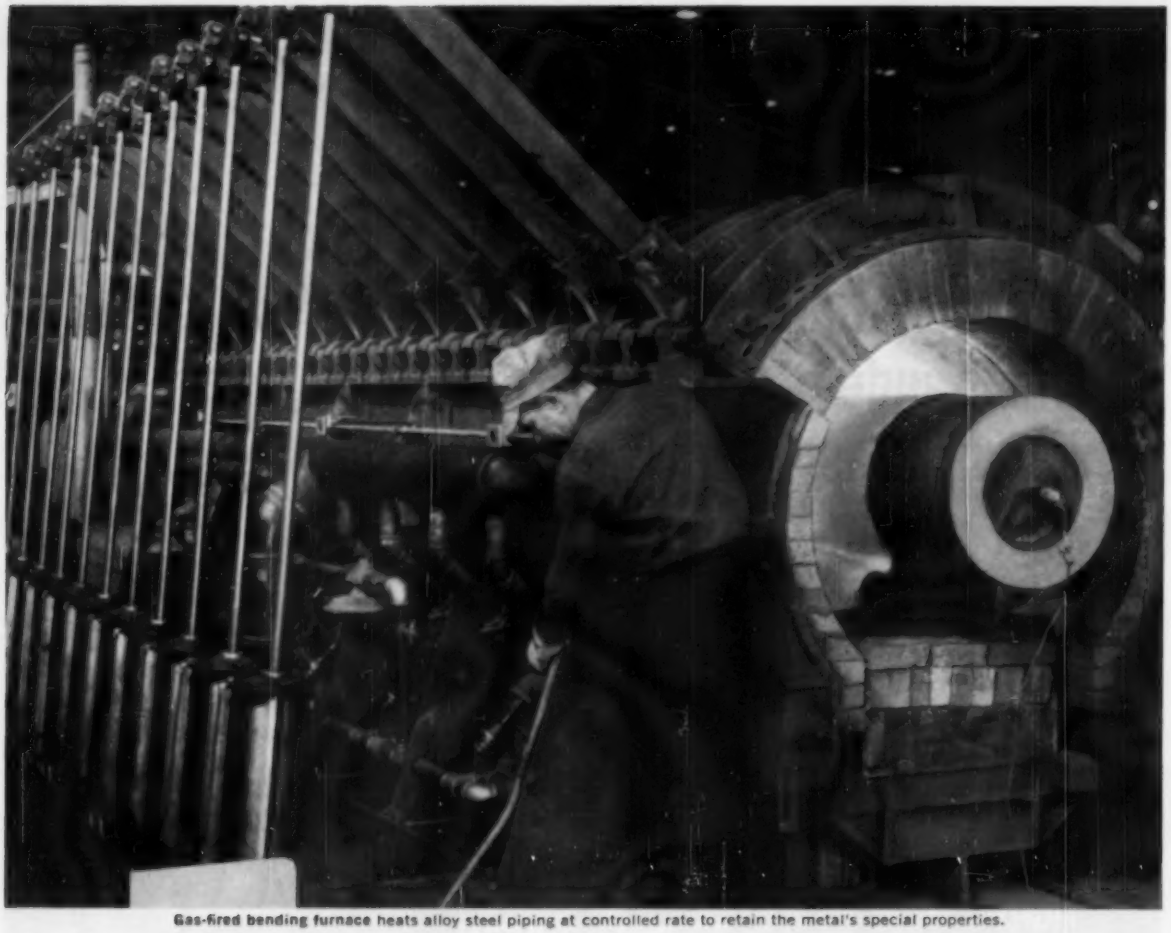
YARWAY
A MARK OF QUALITY IN STEAM ENGINEERING

TIGHT
Sealing valve is time-proven Yarway Seatless design.
TOUGH
Blowing valve features stellite-faced disc and integral stellite seat.
TRIM
Both valves, mounted together, permit more compact piping with reduced weight.

A FEW OF THE MANY SATISFIED USERS: U. S. Sugar Corp. • West Point Mfg. Co. • Halifax Paper Co. • R. J. Reynolds Tobacco Co. • Pulp and Paper Co., Colombia, S. A. • Western Electric Co. • Cornell University



Gas-fired bending furnace heats alloy steel piping at controlled rate to retain the metal's special properties.

Grinnell shop-fabricated piping is 3 ways better than field-fabricated piping

1. Strict quality control. Piping fabricated in the Grinnell shop is made under the strictest quality control . . . with the help of interpretive engineering, metallurgical research, skilled personnel, specialized facilities and rigid inspection at every critical step. Piping fabricated in the field is not made under these ideal conditions.

2. One-company responsibility. Shop-fabrication by Grinnell makes one experienced organization responsible for material procurement, engineering, fabrication and delivery. These many interrelated factors are kept in balance to give you quality at an economy price — no runaway costs.

3. Costs known in advance. With Grinnell, you know all costs — including shop sketches and planning, materials, power services, expendable tools and supplies — *before* you start the job.

Grinnell shop-fabricated piping always meets your exact specifications . . . whatever the size of the job. For your next piping installation, write: Grinnell Company, Providence 1, Rhode Island.

Special jigs and turntables allow Grinnell operators to weld from best positions, assuring superior weld quality.

Lagonda cleaning removes sand, scale, rust, weld spatter, other foreign matter from inside piping.

GRINNELL

Pipe Fittings, Valves, Pipe Hangers, Prefabricated Piping, Unit Heaters and Piping Specialties
Branch Warehouses and Distributors from Coast to Coast

DEARBORN'S FULL-RANGE PRODUCT LINE SERVES ALL YOUR WATER TREATMENT NEEDS

*Check the Scoreboard!...How many of these does your plant need?**

Boiler Water Treatment, Sludge Conditioners and Anti-Foams	Dearborn® 66, 201, 240, 241, 242, 245, 247, 250, 251, 253AF, 281, 291, 659, 669, 679, 689.
Cooling Water Treatments	Polychrome® 501, 505, 525 and Dearborn 533 with Endcor® A; Dearborn 860 with Endcor B; Dearborn 143, 846, 862, 888.
Steam and condensate Corrosion Inhibitors	Super Filmeen® and Super Filmeen 20—filming amines Alkameen® and Alkatrol —neutralizing amines.
Biocides	Dearcide® 702, 703, 707, 711, 717.
Coagulant Aids	Aquafloc 420, 425, 430.
Process Antifoams	Ex-Foam® 630, 631, 635, 636.
Scale and Deposit Removers	Scale-Cleen —inhibited dry acid. Dearborn 134—inhibited hydrochloric acid.
Consulting Service	Before and after sale—covering all your potential water problems from source through reuse to disposal.
Chemical Feeding Equipment; ion exchange resins	Most complete of any water treatment company.
Experience	Three-quarters of a century—longest of any Company in the field.

*Partial list of products. Most are available in economical powder or easy-to-use briquette form.

Unfortunately, there's no panacea—no universal cure-all—for industrial water treatment problems.

That's why Dearborn's full-range product line—the most complete in the industry—is critically important. Because of it, Dearborn engineers need not "make do" with something almost good enough. They have available the exact chemical combination best suited to the job—combinations developed by Dearborn research laboratories and proved in Dearborn's 75 years of experience—longest in the water treatment field. Many of these product combinations are protected by U. S. patents and are available only from Dearborn.

Dearborn's water treatment division has eleven district offices in the United States and Canada and a trained field staff of 90 to serve you—before and after a sale. Call your nearest representative today. Or write for our Bulletin outlining Dearborn services and how they can end your water treatment problems.

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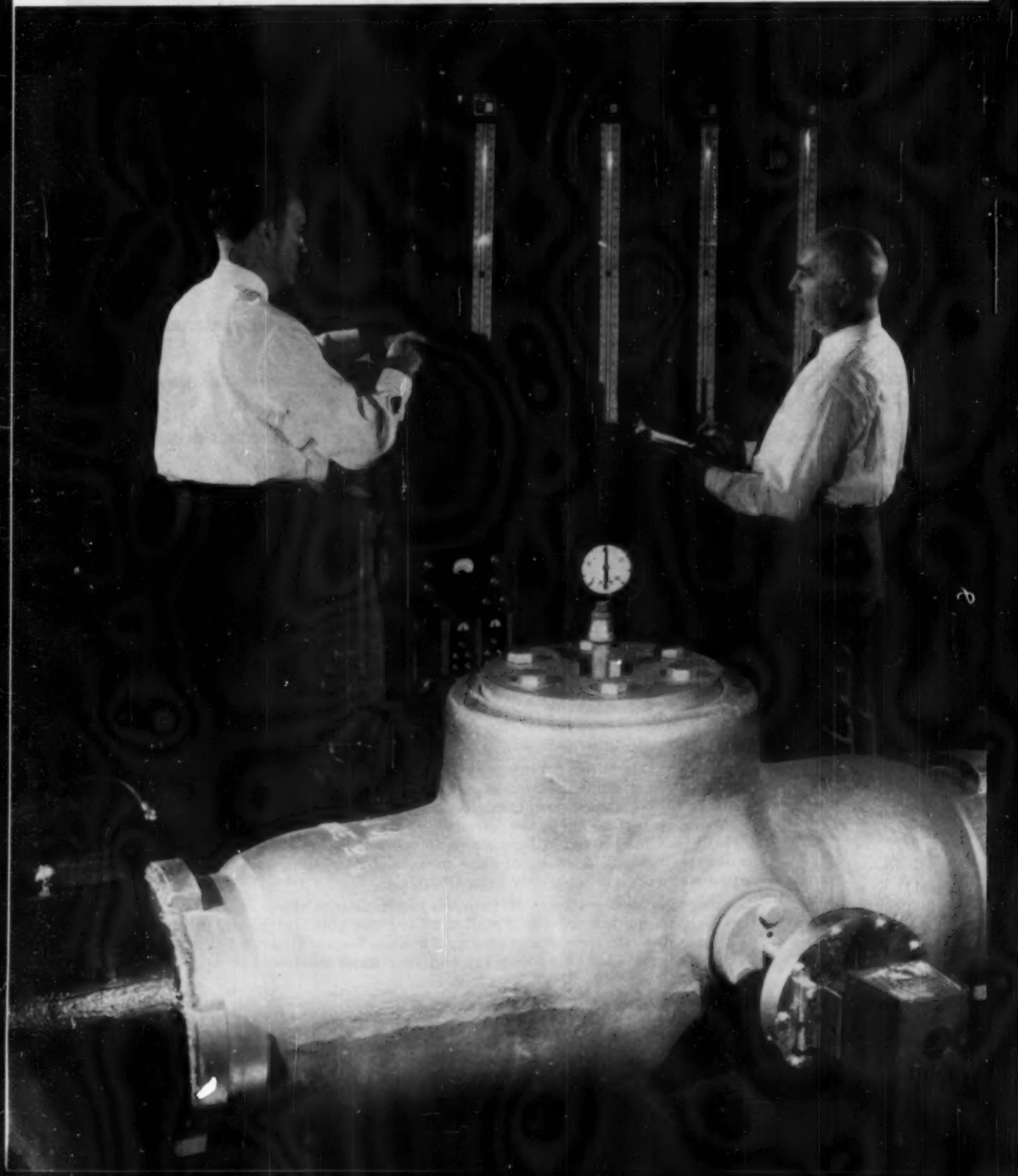
The Story of Edward Research



and the Foolproof Check Valve

The design of the Edward tilting disk check valve started with a single objective: one-piece body construction. Edward designers were convinced that they could achieve this essential objective and, at the same time, assure ease of inspection and maintenance after the valve was welded in the line. Ideally, the valve also had to have these four important operating features: 1) Tight seating; 2) Non-stick operation; 3) Quiet, slamless closing; 4) Low pressure drop. Six years of research and testing gave them these desired features, and made possible this Edward success story.

ONE-PIECE CONSTRUCTION

Both manufacturing and engineering considerations indicated the wisdom of a design with the seat at a right angle to the pipe line. It was also essential that gravity close the disk, whether the pipe was in a horizontal or vertical position. Edward engineers solved this dual problem by welding a counterweight to the disk so that the force of gravity would pull the disk down tight on the seat whether the valve was installed horizontally or vertically. With this new disk idea, the valve seat could be formed of a single circular weld deposit of Stellite, and could be machined and finished through the end of the valve. The resultant one-piece body is virtually impervious to leakage or distortion.

TIGHT SEATING

Getting the disk to seat tightly was especially important because even a small amount of reverse flow was a hazard to pumps and compressors. Edward designers, after experimenting with several pivot positions, pivoted the disk half-way between its center and the upper seating surface. The tapered Stellite-faced disk closes on a tapered Stellite seat in the manner of a globe stop valve. When flow reverses, the larger lower portion of the disk swings downstream while the smaller upper portion swings upstream. Utilizing both gravity and the force of reverse flow, perfect alignment and tight seating are achieved.

SLAMLESS, NON-STICK OPERATION

The unique Edward water flow test loop with its 2,000,000 lb per hour capacity closely simulates actual service conditions. Edward researchers could observe the effects of vibration and water hammer at all stages of tilting disk development. Designing the valve to close quickly—before reverse velocity could build up—virtually eliminated slamming and vibration. Three features make this possible.

First, the disk is dome-shaped to avoid the hesitation of motion characteristic of flat disks. Second, disk travel is minimized by pivoting the disk in the flow stream. Finally, torsion springs enclosed in the pivot pins accelerate closing action from the full-open position. The valve closes efficiently and achieves maximum opening even at lowest flow rates.

LOW PRESSURE DROP

Minimum flow resistance was achieved through painstaking design of all surfaces in the flow line. Full port seat design plus streamlined disk and location of the counterweight out of the flow stream resulted in minimum pressure drop.

A FOOLPROOF VALVE

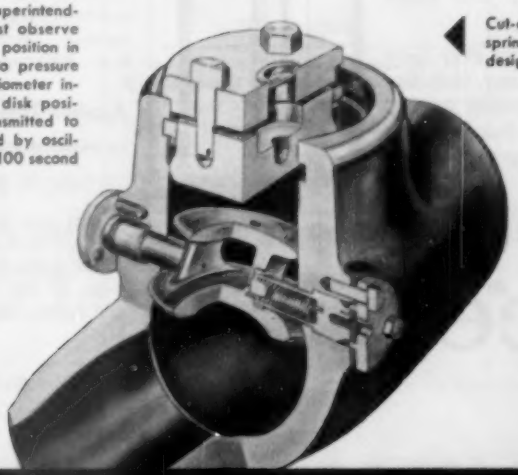
By tackling each problem separately—but always in relation to the entire design—Edward researchers came up with a tilting disk check valve that operated like no other check valve. It was dependable because it always functioned, effective because of its tight seating and low pressure drop, unique because it greatly minimized slamming, vibration, and water hammer.

This is the same tilting disk check valve, developed and patented by Edward Valves, that is so widely used in today's conventional, supercritical and nuclear power stations. Edward Catalog 14-Y gives full details.

Edward builds a complete line of forged and cast steel valves from ¼" to 24" for power, industrial, marine, and petroleum services. For more information, contact your Edward Representative, or write Edward Valves, Inc., 1206 West 145th Street, East Chicago, Indiana. Subsidiary of Rockwell Manufacturing Company. Represented in Canada by Lytle Engineering Specialties, Ltd., 438 St. Peter Street, Montreal. 6823

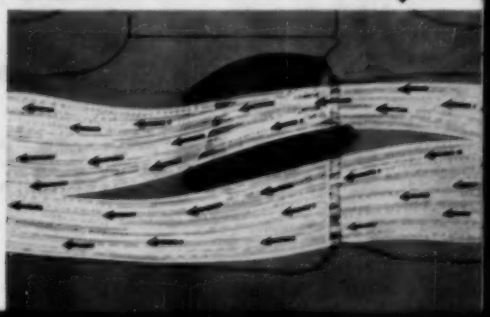
EDWARD STEEL VALVES
another fine product by
ROCKWELL

Director of Engineering and Research L. H. Carr and Plant Superintendent R. E. Rost observe test for disk position in relationship to pressure surge. Potentiometer indications of disk position are transmitted to and recorded by oscillograph in 1/100 second intervals.



Cut-away view of Edward tilting disk check valve shows torsion springs enclosed in pivot pins, pressure seal cover and other design features.

In the open position the disk rests against a stop, thus minimizing disk flutter. Careful design of disk facilitates maximum opening, even at extremely low flow rates.



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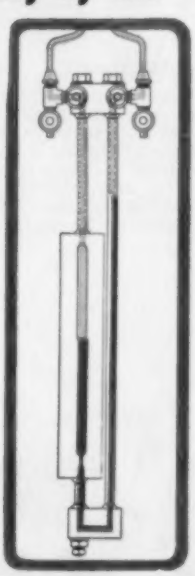

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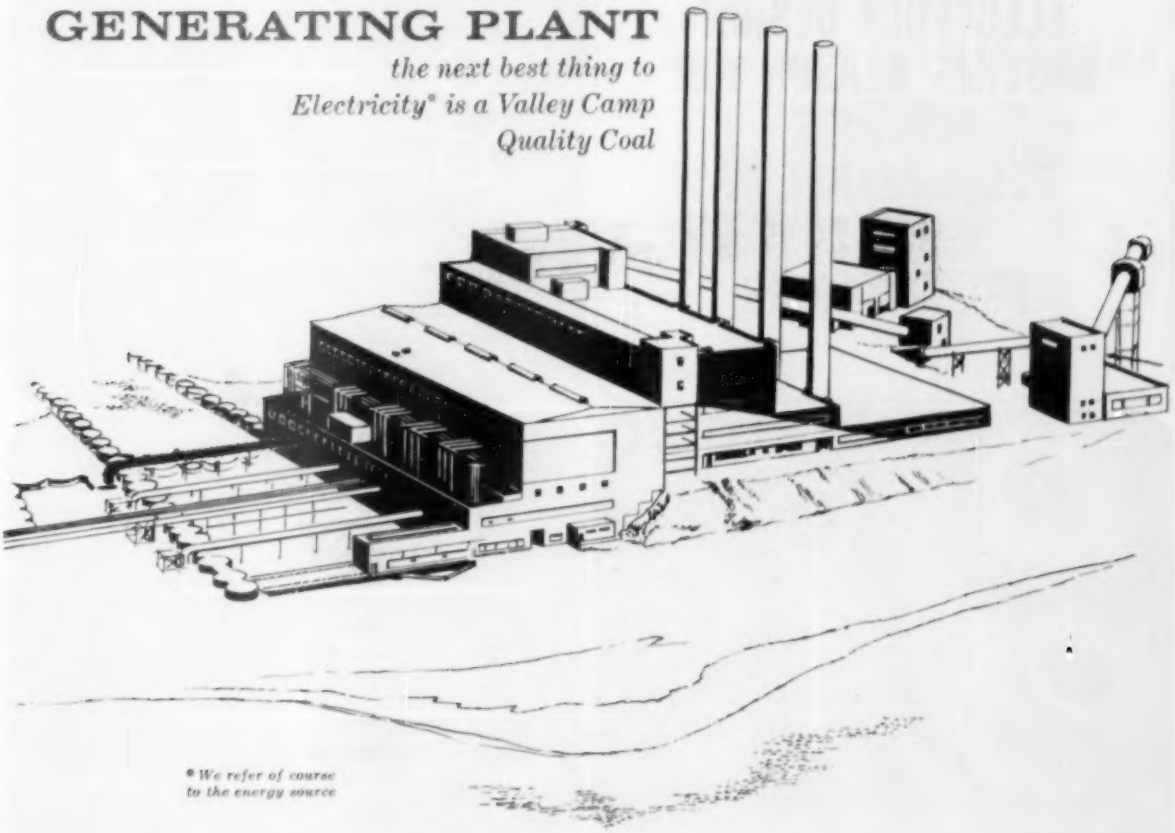

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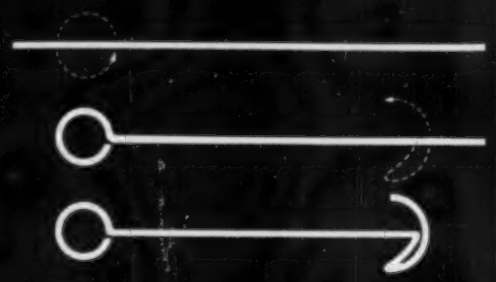
COLLECTING ELECTRODE DESIGN ANOTHER REASON FOR SUPERIOR PERFORMANCE OF BUELL PRECIPITATORS



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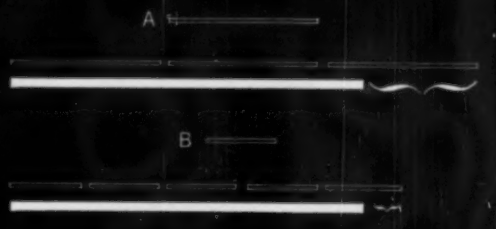

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GUEST EDITORIAL

On Hard-Head Engineers

James F. Fairman

VICE-PRESIDENT, CON EDISON

I am intrigued by the high rating "science and research" apparently enjoys among those who are responsible for some of our magazine and television advertising.

Scientific research, almost every day it seems, is rewarded with break-through after break-through. One day it is a new cigarette filter, the next an astounding new drug to put new zip into an old sag. Or else a magic formula to make straight hair curly, curly hair straight or, perhaps, bring it back if it's gone away.

All, mind you, as scientific as all get-out, as proved by the pictures of men in white coats peering into test tubes.

It makes me a little sad. True, if you define science as knowledge, as they did when I went to primary school, you might make out a case of science for each advance in knowledge, even an improved shape of a liver pill. But a break-through?

Scientific break-throughs, as I understand the term, are pretty rare. Newton's concept of the role of gravity, Pasteur's proof that rabies was caused by germs, tomorrow's isolation of the primary cause of cancer—and the orbiting of Sputnik 1.

Break-throughs, certainly, played a part in the truly impressive advance in applied science since the beginning of the 20th Century. Some closed doors needed unlocking. It is more true that the major part of the progress was due to the day-to-day chipping away at immediate problems by men in industry who find their work interesting, sometimes engrossing, but who would scorn to call it glamorous.

I choose to call these men—and there are some women—the hard-head engineers. Among them you'll find a few scientists, some pure researchers and a great many professional engineers, most of them anonymous.

I know this is true of the electric utility industry, the one with which I am most familiar. In my own company, for instance, we have traveled in the span of a man's lifetime from Edison's Pearl Street power house, where the boilers were stoked with coal brought through city streets by horse and wagon, to our Indian Point station in the Westchester hills where the basic fuel will be uranium and thorium, both unheard of by the man in the street fifteen years ago. And where, incidentally, the operating employees will routinely control esoteric forces known, even a decade ago, only to an initiated few.

We can claim no break-throughs. Actually, in all of electrical history there has been no Copernicus, no Newton or Einstein. To be sure, there were men like Franklin and Volta and Faraday, each contributing a building block. And men like Edison and Westinghouse and Tesla, exceptionally practical mechanics with a gift of putting building blocks together.

Hard-head engineers all of them. Their successes are mirrored in the approach and method of the hard-head engineers in industry today who apply themselves daily to the special needs of the enterprises which employ them and the public these enterprises serve. They seek solutions which meet practical requirements, and which are realistic in economic, engineering and even social terms. They get few laurels and less time to rest on them. One job succeeds another, and they know that for every existing technique and design, there is a better way. They are indispensable to the industry which employs them and, as such, vital to the welfare of the nation.

In this time of international competition in every technical field, our appreciation of the hard-head engineer should give us more comfort than a pathetic faith in miraculous break-throughs.

James F. Fairman

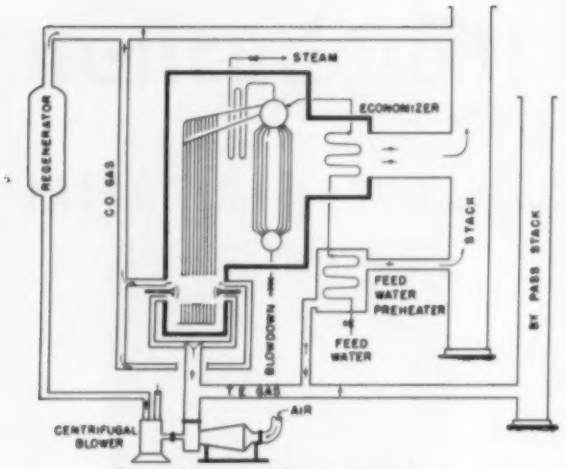

Fig. 1—Gas turbine CO boiler flow diagram

CO Boiler

Regenerator Flue Gas Temperature 1048 F
Steam Rate = 171,000 Lb per Hr at 610 psig and 700 F
Drum Pressure 625 psig
Blowdown = 13,250 Lb per Hr
Feed Water = 184350 Lb per Hr at 318 F
Feed Water Out of Preheater 355 F
Flue Gas Out of Preheater 522 F
Flue Gas Out of Economizer 573 F
Fuel Gas 31,373 scfh = 23.15×10^6 Btu per Hr (HHV) at 60 F
19.32×10^6 Btu per Hr (LHV)
Natural Gas to Pilot 5500 scfh = 5.78×10^6 Btu per Hr (HHV) at 60 F
5.19×10^6 Btu per Hr (LHV)
Samples (Mol % Dry Gas)

Turbine Exhaust Gas	Regenerator Flue Gas	Flue Gas After Economizer
O_2 = 17.3	1.5	4.0
CO_2 = 2.1	9.9	12.6
N_2 = 80.6	79.9	83.4
CO = 0.0	8.7	0.0

A Gas Turbine "CO" Boiler Installation; Economic and Thermodynamic Analysis*

CHARLES BULTZO† Humble Oil and Refining Company

The paper presents a detailed thermodynamic analysis of a combined gas-turbine "CO" boiler installation. Regenerator flue gas with 9 per cent CO is burned to CO_2 using gas-turbine exhaust which contains 17 per cent O_2. In addition, the first costs of a steam-turbine drive is compared to that of the gas-turbine installation. The summary is a comparison of the anticipated efficiency with those being experienced.

ESSENTIAL to fluid-catalytic-cracking operation is the need for regeneration air. During the time of reaction in the hydrocarbon stream, carbon is deposited on the catalyst. In order to remove this carbon, air is supplied in the regenerator and the carbon removed by burning, which produces large amounts of CO and CO_2. The CO, CO_2, N_2, H_2O (due to burning of some hydrocarbons), and remaining O_2 are separated from the catalyst by cyclones. Usually some form of waste-heat recovery is employed to utilize the sensible heat in this gas stream (regenerator flue gas).

High-capacity air blowers are usually used to supply the regeneration air. In the past, large steam turbines or electric motors were used to drive the air blowers. Integral with the design of new cracking facilities is the study of the utility complex, a part of which is the steam-generation capacity. The steam demand of two 5000-hp steam turbines could possibly require additional steam-generation facilities or the purchase of additional electrical power to balance the reduction of existing power-generation capacity due to diverting steam to the new blower turbines.

This paper will attempt to discuss the economic study made that resulted in the selection of two 5000-hp gas-turbine drivers for the blowers and CO boilers used for waste-heat recovery. Also, thermodynamic analyses in the form of heat balances are made on the gas turbines, CO boiler, and the combined cycle.

Selection of Equipment

A number of cases were studied. The common datum was the case which included steam-turbine drivers, which was the low investment case. The final analysis was made using the gas turbines, CO boiler installation which was the most economically attractive case with this low-investment case. These two cases are summarized as follows.

CASE I. This case includes two 5000-hp gas turbines to be used with two CO boilers, each capable of generating 179,000 lb per hr of 600-psig steam. Included in this case was the investment necessary for ductwork and water-treating facilities. The operating cost for this installation included fuel gas to the turbines and boilers, maintenance, taxes, and depreciation. The operating cost credits included were the elimination of purchased power required by Case II, shutting down one boiler house, reducing steam-generation requirements at another, and the subsequent fuel savings Table I.

Presented at the ASME Gas Turbine Power Conference and Exhibit, Washington, D. C., March 5-9, 1961, as Paper No. 61-GTP-1.
† Senior Mechanical Engineer, Technical Division.
Also author of the paper "Gas Turbines, Installation and Operational Problems, and Performance Exhibition" ASME Paper No. 59-PET-9.

TABLE I—GAS VS STEAM TURBINE

Case I	Case II
2—179M lb/hr CO boilers 2—5000-hp gas turbines	414M lb/hr 600 psi steam from yard supply 2—5000-hp steam turbines
Investment: Gas turbines Ducts CO boilers Water-treating facilities	Regenerator flue-gas facilities Piping to and from yard supply
Relative investment $2,165,000	$308,000
Operating costs: Fuel to turbine (+) Fuel to boiler (+) Fuel credit (−) Shut down one BH and reduce prod. at one BH (−) Purchased power (−) Maintenance, taxes, depreciation (+) −$89,000	Purchased power (+) Maintenance, taxes, depreciation (+) +$731,000

Case I versus Case II

Net operating cost advantage, $/year	$820,000
Net investment debit	$1,857,000
Net return before federal taxes, per cent	44.2

CASE II. This case included two 5000-hp steam turbines, necessary steam piping to supply 414,000 lb per hr of 600-psig steam, and regenerator flue-gas-handling facilities. The operating cost for this installation included the cost of purchased power due to reduction of steam available for power generation, maintenance, taxes, and depreciation. Table I summarizes this analysis.

It will be noted that the estimated return on Case I before taxes was 44.2 per cent. Actual cost of the gas-turbine installation was approximately 20 per cent higher than estimated. This increase over the estimate was due primarily to the actual cost of the ductwork. However, owing to an increase in fuel costs and related purchased-power cost, a comparison of the two cases today indicates a return before taxes of approximately 50 per cent.

Heat Balance Gas Turbine CO Boiler

Table II, p 24, shows data taken to effect a heat balance around one gas turbine and CO boiler. Fig. 1 shows the general arrangement of this installation.

Data Qualification

All enthalpy calculations were based on heat content above 83 F, the dry-bulb ambient temperature. For simplicity, the lower heating values of the natural and refinery-gas streams were used in the basic calculations. Samples of these gases were taken and heating values calculated. However, for convenience, the efficiencies are expressed in both higher and lower heating values. Composition of the turbine exhaust gas, regenerator flue gas, and economizer flue gas was determined by Orsat analysis.

The Gas Turbine Heat Balance

Knowing the turbine exhaust-gas composition and the fuel fired, the gas-turbine air rate was calculated using methods contained in the ASME Code. The heat balance around the turbine is summarized in Table III.

TABLE III—GAS-TURBINE HEAT BALANCE

	Btu per hr × 10^6
Heat in:	
Dry air at 83 F	0
Water in air at 83 F	0
Heat of combustion (LHV 944 Btu per scf)	83.07
	83.07
Heat out:	
Load	13.93
Turbine exhaust gas at 842 F	69.07
Losses (estimated)	0.40
	83.40
Difference = 0.33 × 10^6 = 0.4 per cent	
Thermal efficiency (LHV), per cent	16.8
Thermal efficiency (HHV 1051 Btu per scf), per cent	15.1

TABLE IV—CO BOILER HEAT BALANCE

	Btu per hr × 10^6
Heat in:	
Fuel gas fired (LHV)	24.51
Sensible heat in turbine exhaust gas	69.07
Sensible heat in regenerator gas	88.35
CO gas fired	104.32
Boiler feedwater	53.09
	339.34
Heat out:	
Steam 600 psig 700 F	230.99
Blowdown	5.29
Stack gas to atmosphere	88.90
Losses estimated by manufacturer	5.90
	331.08
Difference = 339.34 − 331.08 = 8.26 or 2.4 per cent	
Thermal efficiency (LHV), per cent	69.8
Thermal efficiency (HHV), per cent	68.9
Thermal efficiency (estimated by manufacturer HHV), per cent	65.7

The thermal efficiency (HHV) is approximately 0.5 per cent lower than that estimated by the turbine manufacturer. However, this discrepancy may be attributed to errors in fuel rate, exhaust-gas analysis or the 15 per cent increased capability on the machine at the time of the test.

The CO Boiler

The summary of the heat balance of the CO boiler is given in Table IV.

The Combined Cycle

The combined cycle heat balance is summarized in Table V.

Summary, Heat Balances

The key to the difference in closure on the boiler appears to be the variation of the calculated and measured amounts of CO_2 in the flue gas after the economizer. Owing to the good closure around the gas turbine, the calculated air rate is presumed to be good. However, during normal operation a small amount of the turbine exhaust gas is bypassed in order to maintain the desired feedwater temperature and steam rate. This analysis assumed no loss to the bypass stack. To effect closure, on the basis of bypassing the necessary amounts of gas

(*Continued on pp 26*)

TABLE II—CALCULATIONS FOR HEAT BALANCE

Data Used	Turbine	Blower
T_1	83/78 F	83/78 F
T_2	842 F	273 F
P_1	4.5" H_2O	21.8" H_2O
P_2	10" H_2O	14.5 psig
rpm	6350/5750	5750
Air Rate	Calculated	292,080 Lb/Hr Atmos. Air
Barometer	29.84	29.84

Fuel = 88,000 scfh = 3969 Lb per Hr = 92.49 $\times 10^6$ Btu per Hr (HHV)
83.07 $\times 10^6$ Btu per hr (LHV)

Gas Turbine Heat Balance

Gas Turbine Load

At the time of test, the blower handled 63,786 scfm at 13.91 psia inlet pressure and 83 F inlet temperature. It is necessary to convert scfm to cfm:

$$\text{cfm} = \text{scfm} \times \frac{14.7}{P1} \times \frac{T \text{ inlet}}{520}$$

$$= 63{,}786 \times \frac{14.7}{13.91} \times \frac{543}{520} = 70{,}390 \text{ cfm}$$

Using a Psychometric Chart the water vapor present at inlet conditions was 5997 pounds per hour. The weight of atmospheric air was:

$$W_{aa} = \frac{13.91}{53.34} \times \frac{144}{543} \times 70390 \times 60 = 292{,}080 \text{ pounds per hour}$$

$W_{da} = 292{,}800 - 5997 = 286{,}983$ pounds per hour

	Dry Air	Water Vapor
h at T_2	46.73	87
h at T_1	0	0
	46.73	87

$$\text{Horsepower} = \frac{\text{lb. per min.} \times \Delta h \times 60}{\text{Btu/hp hr}}$$

$$= \frac{286{,}983 \times 46.73 + 5997 \times 87}{2545}$$

$$= 5474$$

Gas Turbine Air Rate Calculation

Fuel Gas Fired

scfh = 88,000

$$\text{mols per hr} = \frac{88{,}000}{379} = 232$$

lb per hr = 232 × 17.1 (mw) − 3969

Combustion of Natural Gas

The combustion of natural gas is represented by the following equations:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

$$C_2H_6 + 3.5O_2 \rightarrow 2CO_2 + 3H_2O$$

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

On the basis of these equations, the amount of the various products of combustion was developed by use of the following table at the top of the next column.

Component	Mol %	Mols/hr	O_2	N_2	CO_2	H_2O
CO_2	0.4	0.92	...	...	0.92	...
N_2	0.4	0.92	...	0.89	...	...
H_2	0.1	0.23	0.23	...	...	0.46
CH_4	94.4	219.00	438.00	...	219.00	438.00
C_2H_6	3.5	8.12	28.42	...	16.24	24.36
C_3H_8+	1.2	2.78	13.90	...	8.34	11.12
		231.97	480.55	0.89	244.50	473.94

Per Cent C in Total Fuel

Component	Mol %	Mols	Mols C	Mols H
H_2	0.1	0.23	...	0.46
CH_4	94.4	219.00	219.00	876.00
C_2H_6	3.5	8.12	16.24	48.72
C_3H_8+	1.2	2.78	8.34	22.24
			243.58	947.42

$$\text{Per Cent C in Total Fuel} = \frac{243.58 \times 12}{3969} = 73.64$$

$$\text{Per Cent H in Total Fuel} = \frac{947.42 \times 1.0}{3969} = 23.87$$

Turbine Exhaust Gas Analysis

Component	Mol %
CO	0.0
CO_2	2.1
O_2	17.3
N_2	80.6
	100.0

Weight of Dry Exhaust Gas

Using the ASME Power Test Code for Stationary Steam-Generating Units, Para. 132:
Weight of dry exhaust gas, pounds per hour

$$= \frac{11\,CO_2 + 8\,O_2 + 7(N_2 + CO)}{3(3O_2 + CO)} \times \frac{\text{Wt. of C}}{\text{Lb of Fuel}} \times \text{Lb. of Fuel}$$

$$= \frac{11(2.1) + 8(17.3) + 7(80.6)}{3(2.1)} \times 0.736 \times 3969$$

$$= 336{,}675$$

Weight of Dry Air to Turbine

Dry Air Lb per Hour = Dry Fuel Gas + H_2O Formed—Fuel

= 336675 + 8531 − 3967
= 341239

Water Vapor in Atmospheric Air

Using the Psychometric Chart, the water vapor in the atmospheric air was calculated to be 6691 pounds per hour.

Sensible Heat in Turbine Exhaust Gas

Component	Mol % × Mol Wt	Wt %	Lb per Hr
N_2	80.6 × 28 = 22.57	77.75	261764
O_2	17.3 × 32 = 5.54	19.08	64238
CO_2	2.1 × 44 = 0.92	3.17	10673
	29.03	100.00	336675

Component	Lb per Hr	h at 842°F	Btu per Hr × 10^6
N_2	261,764	192	50.26
O_2	64,238	178	11.43
CO_2	10,673	183	1.95
H_2O	15,222	357	5.43
	351,907		69.07

Summation

	Btu per hr × 10^6
Heat In:	
Dry Air	0
Water Vapor	0
Heat of Combustion (LHV 944 Btu per scf)	83.07

	Btu per hr × 10^6
Heat Out:	
Load	13.93
Turbine Exhaust Gas	69.07
Losses (Estimated)	0.40
	83.40

Difference 83.40 − 83.07 = 0.33 Btu × 10^6
This 0.33 Btu × 10^6 difference is 0.4% of the total input.

Thermal Efficiency

$$\text{LHV} = \frac{13.93}{83.07} \times 100 = 16.8\%$$

$$\text{HHV} = \frac{13.93}{92.44} \times 100 = 15.1\%$$

CO Boiler Heat Balance

From Gas Turbine Heat Balance on opposite page the weight of dry air to the regenerator was 286,983 pounds per hour. The weight of O_2 and N_2 are calculated:

Component	Mol % × Mol Wt		Wt %	Wt Lb per Hr
N_2	0.79 × 28 =	22.12	0.766	220,113
O_2	0.21 × 32 =	6.72	0.234	66,870
		28.84	1.000	286,983

Regenerator Flue Gas Composition

Component	Mol % × Mol Wt		Wt %	Wt Lb per Hr	Mols
CO_2	0.099 × 44 =	4.36	0.147	42,901	975
O_2	0.015 × 32 =	0.48	0.016	4,723	148
CO	0.087 × 28 =	2.44	0.082	24,009	857
N_2	0.799 × 28 =	22.37	0.755	220,113	7861
		29.65	1.000	291,746	

Water Formed in the Regenerator

By oxygen disappearance, the amount of oxygen that was used to burn hydrocarbons is determined:

$$\frac{\text{Lb } O_2}{\text{Mol Wt}} = \frac{66{,}870}{32} = 2090 \text{ Mols } O_2$$

$$2090 - 975(CO_2) - 148(O_2) - 429(CO) = 538 \text{ Mols } O_2 \text{ to } H_2O$$

$$538 \times 2 \times 18 = 19368 \text{ Lb per Hour}$$

Total Water Vapor Out of Regenerator

Atmosphere	5,997
Burned Hydrocarbons	19,368
Steam Added	10,156
	35,521 Lb per Hour

Sensible Heat in Regenerator Flue Gas

Component	Lb per Hr	h at 1048 F	Btu per Hr × 10^6
CO_2	42,901	241	10.34
O_2	4,723	229	1.08
CO	24,009	251	6.03
N_2	220,113	248	54.59
H_2O	35,521	462	16.41
	327,267		88.35

Feed Water Preheater

Heat picked up in the preheater from portion of turbine exhaust gas:

$$\Delta h \times \text{Lb per Hr} = \text{Btu per Hr}$$

$$40 \times 184350 = 7.374 \times 10^6$$

Required Turbine Exhaust Gas for 8a

Component	Lb per Hr	Wt %	Δh 842–522	Btu per Lb
N_2	261,764	74.4	82	61.01
O_2	64,238	18.3	78	14.27
CO_2	10,673	3.0	83	2.49
H_2O	15,222	4.3	156	6.71
	351,907			84.48

$$\text{Lb per} = \frac{7{,}374{,}000}{84.48} = 87{,}287$$

(Table II—*Continued*)

Turbine Exhaust to Boiler

$$351{,}907 - 87{,}287 = 264{,}620 \text{ Lb per Hr}$$

Component	Lb per Hr	Mols per Hr
N_2	196,877	7031
O_2	48,425	1513
CO_2	7,939	180
H_2O	11,379	632
	264,620	

Products of Combustion of Natural and Refinery Gas

Using the same procedure as in Gas Turbine Air Rate Calculations, on opposite page, the products of combustion of 6250 scfh of natural gas and 31,373 scfh of refinery gas were determined to be:

Component	Mols
CO_2	59
H_2O	156

Composition of Boiler Stack Gases

	O_2	CO_2	N_2	H_2O
Turbine Exhaust	+1513	183	7031	632
Regenerator	+148	975	7861	1973
	1661	1155	...	2605
Fuel	−137	+ 59	...	156
	1524	1214	...	2761
CO→CO_2	− 428	+857	...	...
Mols per Hr	1096	2071	14892	2761

$$1096 + 2071 + 14{,}892 = 18{,}059$$

Calculated Component	Mol. %	Measured Mol. %
$O_2 = \frac{1096}{18059} \times 100 =$	6.1	4.0
$CO_2 = \frac{2071}{18059} \times 100 =$	11.5	12.6
$N_2 = \frac{14892}{18059} \times 100 =$	82.4	83.4
	100.0	100.0

Sensible Heat in Boiler Stack Gases

Component	Mols × Mol Wt	Lb per Hr	h at 573 F	Btu per Hr × 10^6
N_2	14,892 × 28	416,476	127	52.96
O_2	1,096 × 32	35,072	115	4.03
CO_2	2,071 × 44	91,124	115	10.48
H_2O	2,761 × 18	49,698	235	11.68
		587,870		79.15

Sensible Heat in Feed Water Preheater Stack Gases

Component	Lb per Hr	h at 522 F	Btu per Hr × 10^6
N_2	64,942	110	7.14
O_2	15,974	100	1.60
CO_2	2,618	100	0.26
H_2O	3,753	201	0.75
	87,287		9.75

Summation

	Btu per Hr × 10^6		Btu per Hr × 10^6
Heat In:		Heat Out:	
Sensible Heat in Turbine Exhaust Gas	69.07	Steam 600 psig and 700° F	230.99
Sensible Heat in Regenerator Flue Gas	88.35	Blowdown	5.29
Heat of Combustion of CO	104.32	Stack Gases	88.90
Heat of Combustion of Fuel Gases (LHV)	24.51	Losses (Estimated by Manufacturer)	5.9
Boiler Feed Water	53.09		331.08
	339.34		

Difference 339.34 − 331.08 = 8.26 Btu per Hr × 10^6
This 8.26 Btu × 10^6 difference is 2.4% of the total input

Thermal Efficiency

$$\text{LHV} = \frac{236.99}{339.34} \times 100 = 69.8\%$$

$$\text{HHV} = \frac{236.99}{343.76} \times 100 = 68.9\%$$

Manufacturer Estimated HHV = 65.7%

TABLE V—COMBINED CYCLE HEAT BALANCE

	Btu per hr × 10^6
Heat in:	
Fuel gas (LHV)	107.58
Sensible heat in regenerator flue gas less load	74.42
CO gas fired	104.32
Boiler feedwater	53.09
	339.41
Heat out:	
Steam 600 psig and 700 F	230.99
Blowdown	5.29
Stack gas to atmosphere	88.90
Losses estimated by manufacturer	5.90
	331.08
Difference = 339.41 − 331.08 = 8.33 or 2.5 per cent	
Thermal efficiency (LHV), per cent	69.8
Thermal efficiency (HHV), per cent	67.0

approximately 30 per cent of the turbine exhaust gas would have to be bypassed. This amount was felt to be excessive. The other possibilities are small errors in the regenerator flue-gas analysis, particularly the CO and the amount of fuel gas fired to the boiler. An increase in either or both would result in less O_2 and more CO_2 in the flue gas after the economizer. Since the generally accepted instrument error of approximately $2^1/_2$ per cent is consistent with the difference in closure, no attempt was made, other than the foregoing review, to improve the closure on the CO boiler.

From the foregoing it is felt that both the turbine and boiler manufacturers have fulfilled their guarantee requirements. Service factor on the gas turbine has been in the league of 99 per cent, confirming its reliability as a prime mover. Further application of the gas turbine is being considered with waste heat used not only to generate steam but also as a source of preheat on hydrocarbon streams.

Acknowledgments

For the aid and counsel generously given the author during the preparation of this paper, he wishes to express his sincere appreciation to Messrs. M.L. Crow, R. P. Souther, J. F. Hickerson, W. K. Roquemore, and C. A. Webber of Humble Oil & Refining Company. Finally, he wishes to thank his wife Margaret for her kind understanding during the preparation of this paper.

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The Challenge of The Electric Power Industry*

By SHERMAN R. KNAPP

President, The Connecticut Light and Power Company and Edison Electric Institute

OF THE many problems which are of concern to today's managers of the electric power industry, one of the most serious has to do with the future manpower which our industry is going to need. The pattern of growth for the past several decades has been one of doubling every ten years. Our estimates indicate that this pattern will continue for at least the next twenty or twenty-five years. The assets of the investor-owned utility business now total more than fifty billion dollars, and we are spending money for additions and betterments at the rate of about three and a half billion dollars a year at the present time. By the end of this decade, our assets will be over one hundred billion dollars, and annual construction expenditures will be running at the rate of more than six billion dollars annually. By 1980, total assets should amount to over two hundred billion, and the annual expenditure for construction will be at the rate of twelve billion dollars per year. These figures in themselves explain why the availability of well-trained manpower of a high caliber is essential to our industry if we are going to adequately and efficiently fulfill our responsibilities to our customers and the public in general.

I am convinced that young people, supposedly so security minded, are at least interested in the challenges which the job may hold in the future. In this connection, I remember an indoctrination meeting which I attended as a freshman in electrical engineering at Cornell in the fall of 1923, almost forty years ago. At the conclusion of Professor Vladimir Karepettoff's talk to us, one of the freshmen asked him if he thought electric power would ever be transmitted by radio. He answered, "No, I do not think so because I think the power companies will always want to know where to send the bill." In addition to being a world-famous engineer, Professor Karepettoff obviously had a good instinct for business.

In spite of the fact that the electric power industry can no longer be considered a new industry, it is still very much in the growth category as I have already pointed out. This means that there are continually new problems arising which need to be solved. For the last several years there has been an increasing amount of research work done by the industry as a whole, under the sponsorship of the Research Projects Committee of the Edison Electric Institute. This has been in addition to the many projects carried on by individual companies or groups of companies. Last fall, in recognition of the increasing interest in industry research, the Edison Electric Institute established a separate Research Division under the chairmanship of Willis Gale, Chairman of the Commonwealth Edison Co. here in Chicago. At the present time, some nineteen projects are being worked on, including such things as galloping conductors, extra-high voltage cable, flue gas contaminants, fly ash utilization, and tree-growth control. This last item may seem

* Presented from the American Power Conference, Chicago, Ill. March 21, 1961.

to be out of place but its importance is apparent when I tell you that in The Connecticut Light and Power Co. alone, we spend close to a million dollars a year to keep our distribution lines reasonably free from interference due to trees. Since our Company represents less than 1 per cent of the industry, the total amount spent in this category is truly staggering. Anything that can be developed to control tree growth under our lines without injury to looks or health will materially reduce our annual operating costs.

Another project which is receiving considerable attention is a continuous review of the work being done by a number of manufacturers in the field of direct conversion of heat to electric power. Last year an article appeared in the July-August issue of The *Harvard Business Review* entitled, "Marketing Myopia," by Theodore Levitt. He talks about a number of things, one of which is of particular interest to us.

> "This is another one of those supposedly no-substitute products that has been enthroned on a pedestal of invincible growth. When the incandescent lamp came along, kerosene lights were finished. Later the water wheel and the steam engine were cut to ribbons by the flexibility, reliability, simplicity, and just plain easy availability of electric motors. The prosperity of electric utilities continues to wax extravagant as the home is converted into a museum of electric gadgetry. How can anybody miss by investing in utilities, with no competition, nothing but growth ahead?
>
> "But a second look is not quite so comforting. A score of nonutility companies are well advanced toward developing a powerful chemical fuel cell which could sit in some hidden closet of every home silently ticking off electric power. The electric lines that vulgarize so many neighborhoods will be eliminated. So will the endless demolition of streets and service interruptions during storms. Also on the horizon is solar energy, again pioneered by nonutility companies.
>
> "Who says that the utilities have no competition? They may be natural monopolies now, but tomorrow they may be natural deaths. To avoid this prospect, they too will have to develop fuel cells, solar energy, and other power sources. To survive, they themselves will have to plot the obsolescence of what now produces their livelihood."

Just this last January, I received the following letter from a Mrs. Frederick Canter, who lives in New Haven. She says:

> "Mr. Sherman Knapp, President
> Connecticut Light and Power Company
> Berlin, Connecticut
>
> "Dear Sir:
>
> "My husband and I own 400 shares of stock in Connecticut Light and Power Co. and firmly believe in the future growth of electric utilities. It is this belief that impels me to write to you. Recently, I read an article taken from *Kiplinger Magazine* which states that in the next 15 years households will be powered by fuel cells instead of today's power methods. How will this affect your company? Will you research and market these fuel cells or have we invested in the horse and buggy while someone else makes the automobile?
>
> "Sincerely,
> "(Mrs.) Frederick J. Canter"

A few weeks ago I was attending a meeting in southern California, and while I was there I saw a full-page ad in one of the Los Angeles newspapers, published by the Southern Counties Gas Co. of California. The principal lead for this ad said,

> "You'll see the day when natural Gas can run everything in your home!"

The ad then describes the various devices we have heard about recently for converting heat energy directly to electric energy and pointed out that with the advent of these devices, all the electric power that is needed in the home could be supplied by the heat of combustion of natural gas, presumably in some little black box in the hidden closet which Mr. Levitt refers to.

I have cited these instances to point out the importance to our industry of finding out all we possibly can about these new developments and their impact on us. I can agree with much that Mr. Levitt says, but I would like to comment on his concept of the gadget in some hidden closet of every home, silently ticking off electric power. This is technically a possibility, but there are a number of reasons why I think that the day is a long way off when the little black box in the back closet is going to supply all the electric power needed in the home. The greatest hurdle that such a scheme has to contend with in upsetting the existing system of electricity supply is an item that all people in the utility business are well aware of, namely, diversity factor. For instance, it would take a gadget having a capacity of 10 kw in order to supply the electric range of an individual home. On the other hand, it only takes 60 kw of central-station capacity to supply 100 electric ranges on our distribution lines. This is only six-tenths of 1 kilowatt per range or one-sixteenth as much as the 10-kw capacity of the home generator which would be required to serve the individual range. This factor of diversity exists with practically every application of electricity in the home. Its overall effect is that the total generating capacity provided at the central station is only a fraction of the total capacity which would have to be provided by little black boxes.

Another important hurdle for the individual home supply of electricity is the relation between cost per kilowatt of capacity and size of the generator. In practically all devices which we know of, or can conceive of today, the unit cost varies inversely as size. This is clearly evident in our conventional steam turbines and is an important reason for the increasing use of larger and larger turbogenerators. It is likewise evident that in order to make atomic energy competitive with fossil fuels as a means of generating electricity, we must think in terms of large installations in the order of one-half million kilowatts or better.

The combination of diversity and cost-size relationship constitutes the primary reason why we need not be concerned in the near future about our electricity supply systems becoming obsolete. There is still another reason which seems to me to be worth keeping in mind and may, in fact, prove to be controlling. Last December I was privileged to witness a demonstration of a magnetohydrodynamic generator at the Avco Laboratories at Everett, Massachusetts, outside of Boston. This device is a means of generating electricity by forcing hot gases at a temperature of about 5300° through a magnetic field. Whereas the thermal efficiency of conventional steam turbines has an upper limit of about 40 per cent, the magnetohydrodynamic generator offers the possibility of reaching a thermal efficiency of perhaps as high as 75 per cent. It is evident, however, that percent this device is not a simple one like a storage battery, and I seriously question whether many house owners are going to want to play with that kind of a black box. If the MHD principle proves economically practical, it will probably be used in large sizes in central stations and will constitute a further improvement within our present concept of power supply.

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The need for free and open discussion of the problems the steam-raising industry faces in controlling boiler furnace explosions prompted COMBUSTION to stage a forum on this subject a year ago (March, April 1960). This year this same forum treatment was staged under the auspices of the Fuels Div. of the ASME. Last part of three.

Furnace Safeguards Panel—III*

Individual Fuel Dangers

Chairman Summers.... "Let us use that to lead into a question, which is a little out of planned order, and ask what the feeling of the panel is with respect to the relative hazard of the three popular fuels—pulverized coal, oil, and gas. Could I have a show of hands as to whether you feel that all three are approximately equally dangerous? That is eight."

J. U. Baley.... "I am glad we don't fire gas."

Chairman Summers.... "This is usually the reaction of the one who doesn't fire it. He is the most afraid of it."

L. H. Coykendall.... "In preparation for that kind of question I went over a record of explosions that we have had for four years. I will give you the percentages."

Chairman Summers.... "The percentage of installations of each type?"

L. H. Coykendall.... "I didn't get to that, but I have the percentages of explosions on gas, which was 48 per cent; on pulverized coal, it was 37 per cent, and 15 per cent on oil. This is for utility units."

Chairman Summers.... "From your memory is this approximately in the same order as their frequency of occurrence?"

L. H. Coykendall.... "This is a record of explosions reported by our Service Department over a period of four years."

Chairman Summers.... "Were there roughly half of the total number of boilers involved that fired gas?"

L. H. Coykendall.... "I didn't relate it to the total number of boilers in service firing each fuel."

Chairman Summers... "I am asking from your recollection. In other words, as you remember it, would it be approximately half, because it might be significant if you only had a small number of certain boilers and yet had explosions?"

L. H. Coykendall.... "This is a record of explosions that have occurred. This is the percentage that were fired by gas, oil, and coal of the total."

THE SCHEDULED PANEL

Chairman: **W. A. Summers,** Mech. Engr., Ebasco Services, Inc.
Vice-Chairman: **A. W. Hindenlang,** Technical Editor, Combustion Engineering, Inc.

J. U. Baley, Asst. Gen. Supt., Electric Operations, Baltimore Gas & Electric Co.
William C. Beattie, Asst. Vice-Pres. of Electric & Gas Production, Consolidated Edison Co. of New York, Inc.
L. H. Coykendall, Field Engrg. Coordinator, The Babcock & Wilcox Co., Boiler Div.
V. F. Estcourt, Mgr., Steam Generation Dept., Pacific Gas & Electric Co.
C. W. Kellstedt, Production Supt., Production Dept., Consolidated Edison Co. of New York, Inc.
W. L. Livingston, Burner Group Leader, Kreisinger Development Lab., Combustion Engineering, Inc.
R. M. Lundberg, Efficiency Engr., Commonwealth Edison Co.
E. R. Mitchell, Head, Combustion Research Section, Fuels & Mining Practice Div., Mine-Branch, Dept. of Mines & Technical Surveys, Ottawa, Ontario, Canada
C. E. Parker, Asst. Genl. Supt. of Generation, Public Service Electric & Gas Co.
R. I. Wheater, Chief Proposal Engr., Steam Dept, Foster Wheeler Corp.

UNSCHEDULED PARTICIPANTS

Russel R. Beal, Bailey Meter Co.
Charles D. Birget, Commonwealth Associates
L. F. Deming, U. S. Bureau of Yards and Docks
M. D. Engle, Pennsylvania Power & Light Co.
J. C. Falkner, Copes Vulcan Div. of Blaw-Knox
Paul Grossman, Combustion Power & Equipment Ltd., Montreal
W. T. Reid, Battelle Institute
Temple Voorheis, Coen Burner Co.

Chairman Summers.... "Of the boilers that did explode?"

L. H. Coykendall.... "That is correct. It is a little bit different on industrial boilers. On industrial boilers, which have a higher percentage, surely, of boilers fired by gas and oil, there was 61 per cent on gas as compared to 48 per cent on utility boilers. There was 21 per cent on oil. There was 12 per cent on pulverized coal, and 6 per cent on sawdust and other waste fuels."

Chairman Summers.... "Would it be possible to relate this to total percentages installed, not today, but prior to the time some of this is published? I think it would be more meaningful because this way it could be highly distorted."

L. H. Coykendall.... "It is hard to do that because so many of the boilers are on dual fuels. Sure, we could go over the record of our sales for that period and total up the number but this would not be a true picture either of the total number of boilers in service for each fuel. This is a rather big job to do. I thought of doing it myself, but I thought these percentages of the total of explosions would be interesting because in each case the gas is the highest percentage. This does not, by the way, include package boilers."

Chairman Summers.... "But the ratio between gas and powdered coal is surprisingly close."

L. H. Coykendall.... "On utility units, that is right."

Chairman Summers.... "Is there anyone here who has a strong feeling that gas is by far the most dangerous fuel? I see one."

L. H. Coykendall.... "I believe that the reason for this is the general feeling throughout the industry that gas is an easy fuel to fire, and therefore, the operators become lax with gas. It is like dynamite if you don't handle it right. Therefore, you get the highest number of explosions with gas because it is so easy to fire with it. It is so easy to handle that the operators become lax. Also, there is something in management on this business. Men like Jim Baley

and others in his position had better set up some good operating procedures and then make darned sure that their operators follow them. I don't mean to imply that Jim has not done this because I know he has, but there are a number who have not done a good job in this area."

Chairman Summers.... "Is there anyone who feels powdered coal is the most dangerous fuel to fire? How about oil?"

Communications

A. W. Hindenlang.... "I don't think any fuel is more dangerous than the one you are firing at the moment. Could we get back to the question of communications, which I think is one of the most interesting things that has been brought up today and get anybody on the panel to volunteer just what information should be given to the operator? Is television the answer? How much can he handle?"

L. H. Coykendall.... "I think that the units today are getting so large and the complications of the indicators and the charts and all of the things that the operator has to check are coming to the point where we must put permissive interlocks in if we are not going to fully automate. Finally I hope in the not too distant future we will go to complete automation, so that the operator is supervisory over an automated system. He is watching it. He is there and so on, but he is not operating it.

"Right now you are asking one man or at the most two to do this. In some of the control rooms they have three men operating two units, and we are putting instrumentation spread over a 20-foot length of the room on both sides, and we are asking the operator, when something goes wrong, to determine right then what the heck he should do. This is asking too much of that man.

"Besides putting in all this instrumentation, television, fuel cutbacks, fuel-air ratios, and all of these things we are going to have to have them interlocked so that the operator can't go wrong. He is still there to correct things and bring them back when they are off and so on, but I believe that we are just asking too much of that one man in an emergency condition. We are going to have to put these interlock systems in."

V. F. Estcourt.... "I hope that this is not giving the impression that modern jobs aren't very amply interlocked. We are talking now apparently as though we had nothing today, and we had better get busy and put something in. That is a rather distorted view of the situation.

"The same pitfall seems to occur when we talk about automated plants. Our plants are about 85 per cent automated at the present time, but I think we ought to be careful how we use these terms.

"The other point is on the question that was asked as to what information you think should be communicated. I don't think that we can handle such a subject here today. Would you want to block off all the feedbacks in a fully automated system today here and now?"

Chairman Summers.... "You couldn't get any place. In other words, you have to provide communication of one kind or another."

V. F. Estcourt.... "It is just as important whether the job is 100 per cent automated or only 85 per cent automated. You have to have either instrument communication of vital functions or you have to have voice and sight communition. One way or another you must have essential communication."

R. M. Lundberg.... "Because of our lack of ability to engineer into each of our large units all of those requirements which we would like to have, we are still required to give the operator certain details which can best be handled by automatic controls. We are sure that hardware is available but we feel we haven't

progressed enough to use it.

"In the meanwhile, there exists a transition period, at least within our organization. We are training all of our crews in our units on an annual basis. Using small groups, we go through dry runs on boiler light offs.

"We have recognized that with job rotation and shift rotation that, unlike the jet pilot who goes up regularly with the same co-pilot and flight engineer, we only take off our planes every six months or so. We don't give our fellow a chance to work with the same co-pilot or same flight engineer or even the same radio operator for a period of five to ten years. As a result, we are trying to obtain a very exact sequence in start up procedures in order to reduce some of the errors in communication which can creep in."

Equipment Shutdown

Chairman Summers.... "I think that is an excellent comparison. We will have to move on now. There is a specific question that came up. I think most of you will be interested in this question. Is a furnace overpressure interlock to trip a unit following a tube rupture or other causes of overpressure considered beneficial in avoiding an explosion? What should be the set point and sequence in shutting down combustion equipment? I would like to start off on this with Mr. Mitchell because he has some other information on pressure furnace surge detection.

E. R. Mitchell.... "I don't know that I can answer the question as you posed it, Mr. Chairman. It has been fairly well established that a furnace can be operated safely with a sensitive pressure differential indicator controller. A tube failure, a serious rupture, would with such equipment automatically shut the apparatus down. Whether or not it is a correct procedure, this would have to be the end result."

W. C. Beattie.... "I would like to answer part of that question, if I may. Where the boiler tube ruptures and you are on powdered fuel, the boiler should be tripped out because, in my opinion, the escaping steam along with the powdered fuel will generate a percentage of water gas. I have already encountered many years ago a water-gas setup where I had the explosion occur and the second explosion occur in the economizer section which blew out the side of the economizer. I definitely would say an overpressure switch that is picking up the overpressure due to a ruptured tube should trip out the fuel when it is a powdered fuel."

Chairman Summers.... "Do you have any suggestion on settings?"

W. C. Beattie.... "My only suggestion is as soon as possible, and I have to say within a reasonable limit of the pulsations that you normally get on the pressure furnace. That will depend upon again your installation, whether it is an ID, FD or only FD fan installation."

C. W. Kellstedt.... "We have pressure installations on our new units, and we have operated on tube ruptures. I think we have found, as Mr. Beattie said, that we have to set it just above what the normal operating or pulsating, I should say, condition is in the furnace and get it as closely set to that point as possible.

"I do not think the device as such is any protection against the furnace explosion. By the time that operates the boiler is in pieces."

Chairman Summers.... "That hasn't been our experience. We have had very good luck with it on just this type of accident. We find that you get a surge when the

tube first lets go that is usually sufficient to trip this device."

C. W. Kellstedt.... "I mean it would not prevent loss of flame explosion in it."

Chairman Summers.... "But I think it is a type of device that can prevent the second explosion."

C. W. Kellstedt.... "That is right. We trip out completely on furnace pressure."

L. H. Coykendall.... "Bill, you asked for pressure settings. We, as manufacturers, on a suction fired unit designed our units for plus or minus 7 inches of water pressure. We recommend setting the furnace overpressure trip to trip at these points on a suction unit. We set it at this point so that there are not too many false trips which occur if they are set too close to the operating pressure.

"On a pressure-fired unit, we would recommend setting them at somewhere between 130 and 150 per cent of the operating furnace pressure.

"We designed for 150 per cent of the operating pressure at full load. Again we would recommend setting them at this point so that they are far enough above the regular operating pressure that you don't get too many false trips."

C. E. Parker.... "We looked into furnace overpressure trips or alarms and received recommendations from the boiler manufacturers, and we decided while they will not prevent all sorts of explosions, they may help to avoid a second explosion, which could follow a tube rupture.

"They might also prevent blowing a seal. If you have an ash pit with a water seal, an over-pressure trip is desirable and in general we think there are enough benefits to justify putting them on our next boilers."

V. F. Estcourt.... "I would like to ask if you were talking about suction type and pressure type furnace seals. If you are talking about suction type furnaces, I assume that you haven't ended the job by just tripping the fuel out. Is that all that you do in the case of a tube rupture?"

C. W. Kellstedt.... "Can I answer that for Con Edison? We trip the fuel, the air, the fans, the generator, everything, all in one fell swoop."

V. F. Estcourt.... "We try to restore negative pressure in the boiler by rebalancing the two fans. Otherwise you have quite a mess on your hands."

C. E. Parker.... "I was speaking of pressure boilers, and we would trip everything."

R. M. Lundberg.... "One of the items that we have been preoccupied with has been the incidence of false trips, so we use two limit switches connected in parallel so as to alarm and in series to trip."

Furnace Protection

Chairman Summers.... "We will have to move on now. There is one other question; I am going to put two in one. Do you feel that the type of firing system used has any bearing on the explosion situations, and do you feel that the furnace protecting system should be on a per-burner or on a per-main-flame-envelope basis?

"I would like to run right down the panel and have each one take 30 seconds to answer each of the two questions. We will start off with Mr. Wheater."

R. I. Wheater.... "In so far as the question is concerned, we believe that any of the types of firing that are normally used today can be safely protected. It is true that some have to be treated differently than others, but suitable devices can be made available to protect a furnace with any of the conventional firing methods."

Chairman Summers.... "Do you feel the protection system should be on a per-burner or furnace or flame envelope?"

C. E. Parker.... "That is a pretty difficult question to answer in 30 seconds. We have flame detectors on each burner that would trip a particular burner under certain conditions and only trip that burner. Under other conditions, other kinds of failures, we will trip the whole unit."

E. R. Mitchell.... "I feel that for most fuels the protection per flame is probably adequate except for lignite. In that case it is per-burner definitely."

R. M. Lundberg.... "We have done quite a research job over the last year on Flame Eye, purple peepers, Bailey type, and I guess there are a few others. We are working on a per-burner basis, on a per-igniter basis, on a flame envelope basis. Frankly we don't know. We would like them all to be safe every step of the way.

"As a simplification we have tried on some jobs to take care of the first four burners that we cut in and then take care of flame envelope."

Chairman Summers.... "So that you are differentiating between low-load operation in effect and high-load operation?"

R. M. Lundberg.... "Yes."

W. L. Livingston.... "In this case I would say when you are at low load you probably have more than one flame envelope. We would definitely recommend that protection be confined to a per-flame-envelope basis because, after all, it is that flame envelope that is going to get you in trouble if you are going to get in trouble. The fact that a burner may influence the flame envelope is important, but the end result is the flame envelope itself. If the burner malfunctions and does not affect the main flame envelope, why shut it off?"

Chairman Summers.... "You are saying by definition it hasn't malfunctioned then?"

W. L. Livingston.... "The flame envelope hasn't malfunctioned."

C. W. Kellstedt.... "I think that during startup of a boiler we should be on a per-burner basis, and that once we get above the point at which we consider we have a stable flame, even without an ignition burner, we should go on a total flame envelope basis."

V. F. Estcourt.... "The last speaker's analysis would meet our situation. We are concerned with the loads below 50 per cent. I don't think you can handle a flame envelope concept at these light loads."

L. H. Coykendall. . .

"I believe that any system that cannot maintain ignition at the burner is potentially dangerous. I would not like to see, say, half of the burners in the boiler with ignition at the burners and the other half with no ignition at the burners. Regardless of the flame envelope, I believe that if you are pouring air and fuel in a large range of mixtures in burners that are not ignited, they will try to ignite back to the source. The flame will carry back there from the main envelope, and they can cause fluctuations that will ultimately put out the furnace and cause a very dangerous condition.

"Therefore, I believe that under any condition you should cut out the burner if ignition on that burner is faulty and fails."

W. C. Beattie. . . .

"I will echo the sentiments voiced by my colleagues with one exception. Being always the exception here, I have to say this. When you are lighting off the boiler, and you have few burners, you can observe the few burners. I would like to have an individual monitoring of burners no matter how many burners you have functioning, but when you get to 32 as a number of burners in there, you can't tell whether the sixteenth burner is functioning rightly or the seventeenth or eighteenth or which one is doing the job. My answer to the question is definitely individual burner monitoring, but at the present time I am forced to go ahead and take the overall flame condition of the boiler as the monitoring that we are now doing."

J. U. Baley. . . .

"We operate so that we can tolerate the loss of one unit in our system, and I would hope other people do. I would hope that operators in my company would pull the plug if they had any question about whether the fire was in serious danger in their furnace. I think they would.

"I think that many of the cases of serious furnace explosions that I have some familiarity with may have resulted because the operator, either because of false pride or trying to hang on because the last time he dumped his boiler he got hell from his boss, tried to hang on until he did have something serious happen.

"I think we ought to pull the whole unit if the operator at any time feels he is in trouble in his furnace or any other critical piece of equipment."

Chairman Summers. . . .

"I think the answer to this flame envelope versus individual burner has also answered the first question, which was whether or not the firing system has to be considered with the furnace design and whether it affects how you handle it. I believe that this showed up in the discussion that came forth.

"Gentlemen, we are rapidly running out of time. We have twenty minutes left in the session. We would like to open it for more floor discussion. I would like to try and summarize briefly what has come out of the panel thus far.

Summation

"I feel that basically there has been what, at least to me, was surprising. That was that there was more agreement than I expected; the agreement being somewhat more than there was approximately two years ago when this subject was discussed.

"Basically, it looks like there is a fairly universal acceptance of more communications, to use Mr. Estcourt's words, between the process and the operator. This seems to be one of the most important items.

"Second, there was no question as to the necessity of all types of devices, both post-difficulty devices, such as flame detectors and pre-difficulty detectors, such as furnace pulsation monitors, draft switches, fuel-air ratio devices or that type. I think it does point out that there is a tendency to try and anticipate the trouble before it begins and to shut the

unit down before we get over the hump that Mr. Livingston so dramatically demonstrates with his equipment, and to use the tripping on flame failure as a final resort.

"The matter of hardware difficulties was certainly less of a problem to our panel members than it has been to us. We have had a lot of trouble with limit switches, and, therefore, it is some degree of encouragement.

"Finally, I think that it shows a great awareness on the part of major segments of our industry. There has obviously been a considerable amount of work, thought and effort put forth on this subject in the last two years Even though last year, 1959, seemed to roll up its normal toll of boiler explosions, which is running something close to one a month, there is some hope of our doing better in the future, based on this kind of work. I would like now to ask for specific questions from the audience."

Temple Voorhies....

"I was a little puzzled by the seeming conclusion drawn from the first panel question, which resulted in a vote of 8 to 3, I believe, in favor of cutting off the fuel in the event of a fuel-rich furnace condition. I think possibly my trouble stems from the fact that I have had no experiences at all with pulverized coal.

"But from the point of view of a burner designer and manufacturer, and from personal experience extending over quite a few years, I have never seen a flame on either oil or gas in a furnace which was operating and which ultimately resulted in a complete flameout from an overrich fuel condition. In other words, going into the heart of the burner, the air and the fuel, in industrial burners, mix in the burner. It is impossible practically to reduce air flow to zero, even if the fan stops. Consequently, in our experience—certainly in my own personal experience—the furnace condition can result in maximum fuel flow, even with fans off and stability of the flame seems to be excellent. I am just wondering about this. I don't know whether the question put to the panel should be rephrased and made two questions: one, coal, and the other oil and gas. It worries me a little bit because I don't believe that the conclusion that Mr. Estcourt drew was actually a minority conclusion, certainly from the point of view of our experience on package boilers, which are very cold and do not use pre-heated air in the smaller sizes.

"It is recommended to cut fuel in a fuel-rich furnace, and we don't think this is sound."

C. W. Kellstedt....

"Mr. Estcourt's recommendation was different. The question had to do with whether we should trip it or not."

T. Voorhies....

"I am talking about tripping."

W. C. Beattie....

"You said 8 voted we would trip. Eight voted we would not trip."

Chairman Summers....

"The question was a little different one. The question that was voted on was this: Is there a safe way to shut down under these circumstances? There were eight who said no, no matter what you do there is no theoretically safe way to shut down; you are in serious trouble."

W. C. Beattie....

"The question was also put in this vein, if there was a flameout. It was answered in the terms you are using. I personally was thinking of an entire flameout. Vivian described a secondary combustion, which wasn't in my book a flameout entirely. He had a flame there. He gradually worked that flame back. That is the same thought that you have in mind, if I understand your point. When I was answering, I was thinking of a distinct flameout."

C. W. Kellstedt....

"I think Mr. Livingston has the best answer of the safe way to do it, which was furnished by an operator."

W. L. Livingston....

"The operator's comment was if you had a fuel-rich condition, to keep it until the next shift came on. (Laughter)

"However, I would say that the fact that you have not experienced a fuel-rich flameout would probably be because I don't know of anybody who would want to show you how we got a fuel-rich flameout during operation. It is conditions that occur when you are not there watching it, when you are not trying to put the fire out by a fuel-rich condition, that is the point we are most concerned about."

Editor's Note:

The controversy on fuel-rich flame-outs may be clarified by the observation that it is the apparent flame-out that often causes trouble. Flame may not be lost at all but if the furnace smokes up to the point where the flame detectors signal that flame has been lost the results can be disastrous. Fuel is tripped (conventionally) and the saturated furnace mixture must pass through the explosive range before a restart is made.

V. F. Estcourt....

"Just to clear up any confusion that Mr. Voorhies has.—I believe everybody understands it now—I want to be sure for the record that Mr. Voorhies doesn't think I voted to trip the boiler out on a fuel-rich mixture. As was explained, somebody on the panel came to my rescue and stated that I believed that the only possible way of getting out of that mess is to gradually reduce the fuel. It may take quite a little time to get the boiler back, if you are going to get it back without an explosion."

T. Voorhies....

"My question really was whether more of the panelists would not have voted with Mr. Estcourt in terms of gas and oil. I don't know about coal."

L. H. Coykendall....

"I don't think it makes much difference. With coal also I believe that if you have a fuel-rich mixture and you do not get a flameout, the best method to use is what Mr. Estcourt said, to try and nurse your fuel back down until you do get the right condition.

"The question was put this way, and that is: If you had a flameout in a fuel-rich mixture, how you get a flameout under this condition I don't know, but if you have a flameout in a flame-rich mixture, what would you do?"

R. M. Lundberg....

"If you look at the fuel-rich situation and Mr. Estcourt's summary of this, he is saying that you have an unsafe condition with a safe operator—himself. I am concerned about the unsafe condition with a normal operator. I don't think all operators can be expected to handle this safely. I have been through the same situation that Mr. Estcourt described and I was scared stiff."

C. W. Kellstedt....

"You have just got to be lucky. That is the answer."

R. R. Beal....

"I would like to speak for Bailey Meter on the last subject pertaining to the matter of whether or not you should monitor the individual burners or the flame envelope. I think past history was more or less dictated by the availability of adequate hardware, whether there was a reliable flame detector available for the package.

"Developments in the past year or so have indicated, at least to the Bailey Meter Company—and I am sure to some of the manufacturers of similar equipment—that there is hardware now available that can satisfactorily monitor gas fires and oil fires and even coal fires for the majority

of types of installations.

"However, there are exceptions to the rule, where the flame envelope must be monitored, rather than the individual burners.

"We are confident that we have the equipment to do this type of job, and, as acknowledged by some of the members of the panel, automation, is with us for both oil and gas firing, and I think we can say that the same thing will be true in the very near future for coal firing."

V. F. Estcourt....

"I would like to add one word to the rich mixture deal. I don't think it is a healthy thing to dust it off by merely saying that if you are lucky you will get out of it. That isn't a very scientific way of looking at this thing.

"I think there are very good reasons why you can get out of it if you follow the procedure of reducing the fuel slowly enough. It is the sudden influx of a change of mixture that is more likely to set off the explosion than anything else. If you will come down gradually enough, you will get out of it.

"It is begging the question to say that probably some of your operators won't do it right. That is another matter. But the point is that we should stay with the engineering approach to this thing. Let us agree, if we can, that these things are not luck. We shouldn't talk that way about them."

Chairman Summers....

"Wouldn't the best engineering approach be to keep from ever getting the rich mixture to begin with?"

V. F. Estcourt....

"Yes, certainly it would. I question whether you are going to arrive at that point where you will never be faced with a rich mixture, even with a fully automated job.

"There is another note of caution that I think should be sounded, and that is if any of you think that because you have had operating errors that when you go to full automation that will solve your problems, I would like to observe that the operator that is most likely to get the automated job into trouble is still the inexperienced operator.

"We shouldn't be retreating in self-defense into more automation. We cannot overlook the training of operators. When you have a fully automated job, the problem is going to be enhanced many times because, as has been brought out here, then you have very little opportunity to train your operators. Pretty soon they won't know what to do if something does happen.

"In fact, I already know of a case of that nature. Let us take this case of having competent people around the job seriously, whether we have automation or not."

Chairman Summers....

"I think just to comment on that automation aspect, though, that it behooves the designers of automation equipment then to make the automation system sufficiently flexible and sufficiently intelligent to operate under varying circumstances.

"When the automation is not running, should it go down, we will have a problem, because I agree completely that an operator who has not had a chance to operate for maybe one or two years has certainly lost the touch."

W. L. Livingston....

"I would like to comment on Mr. Estcourt's statement about the safest way to shut down the furnace on a fuel-rich flameout. I would take exception. I feel that slowly cutting back the fuel on a fuel-rich flameout is the most unsafe thing to do, rather than the safest."

V. F. Estcourt....

"I would like to say that my comments were not applied to a flameout. I have never heard of a flameout of a rich mixture. Possibly somebody

has gotten that far in the hole, but I don't know of any such case."

Chairman Summers.... "It has happened unfortunately."

R. Grossman.... "I gather, gentlemen, that we still will have some explosions unfortunately in times to come. There happened to come to my desk the other day a little clipping from the October 17 issue of *Chemical Engineering*, which I think has some points of interest. May I read it?

" 'A system that suppresses gas or dust explosions almost before they start and a detector that reacts only to flame are two new weapons in the battle to protect workers and property from unexpected disasters. Acting within a few thousandths of a second after an explosion has been triggered, a combination detector-suppressor system developed by **Fenwal, Inc.**, of Ashland, Massachusetts, springs into action, snuffs the blaze out before it propagates. The system stems from British work in World War II to protect aircraft fuel tanks hit by incendiary shells. Unit detectors sense unusual rate of change of pressure or temperature as explosion starts, then fires a small explosive charge in the heart of the suppressor that splits the casing and sprays liquid to extinguish the reaction.'

"There is some mention of Thomas Edison Industries."

A. W. Hindenlang.... "I was afraid somebody would bring that up."

L. H. Coykendall.... "I saw that article, and I came to the conclusion that this system is not applicable to boiler furnaces. The sensing devices that might be used for that in a boiler furnace that is operating, let us say, at full load, at a temperature of 2500 to 3000 degrees, I don't believe have been developed yet. Therefore, I don't think that that system could work, even though the sensing device had been developed. I am afraid it wouldn't work in a boiler furnace."

W. L. Livingston.... "I would like to add that this device, by their own admission, is now confined to relatively small chambers. In an explosion the flame propagates at about the speed of sound. The principle of this Fenwal device is to get some advance pressure waves. The size of the furnace that we have today is so large and this advanced pressure wave is about a constant with the flame front, so that by the time this sensing device did really detect an explosion, whether it would throw in the inert material or not, it just wouldn't be fast enough or in time to prevent damage.

"We only require about four or five pounds in a furnace to require damage, which is very low relative to the kind of containers that they are talking about."

A. W. Hindenlang.... "Before closing the subject, we might comment that Fenwal is working on furnaces at this time. Perhaps at this meeting next year we will have something to talk about."

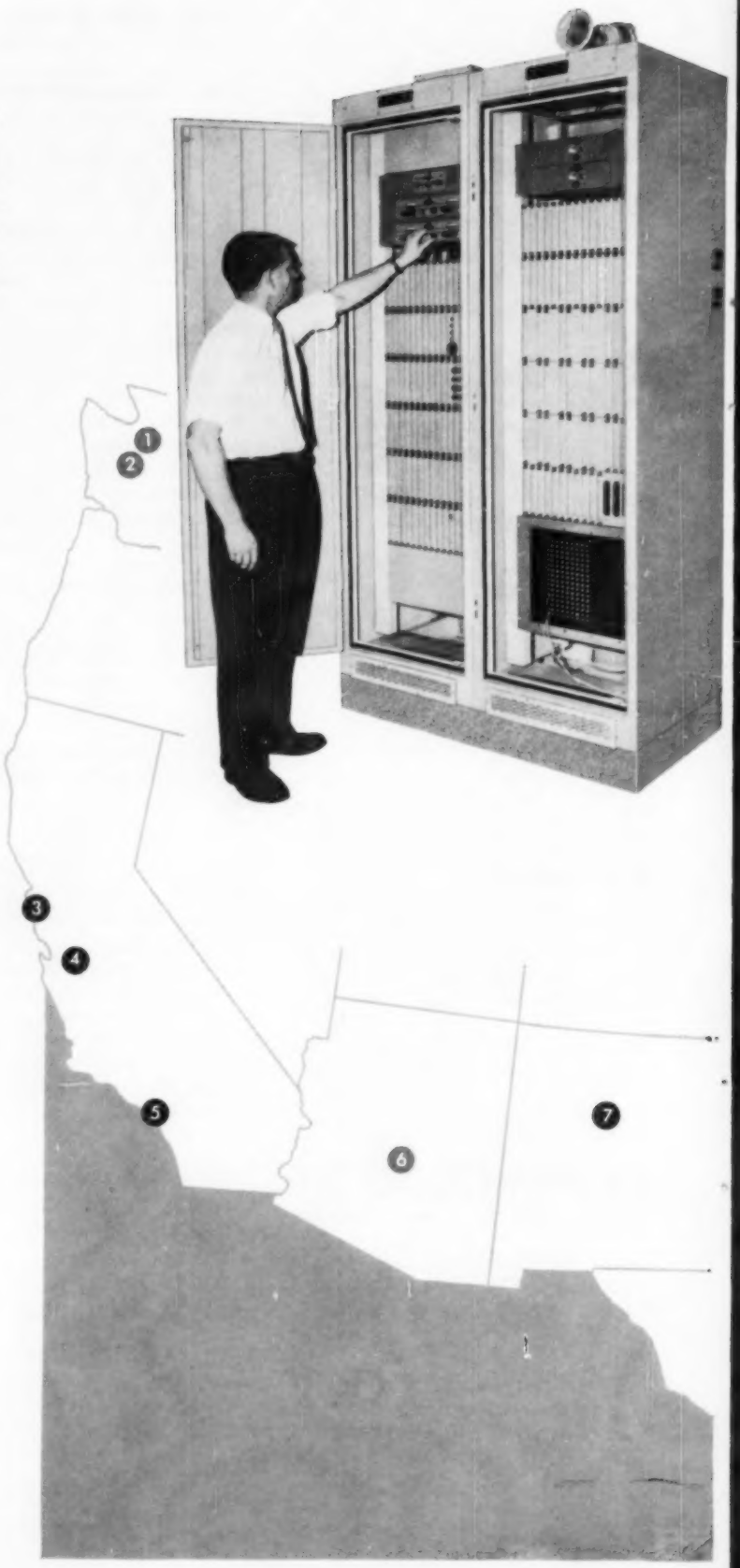
Editor's Note: On pages 17 and 18 we have inserted a postcard on which we ask you to give us your reactions to the articles in this magazine. Will you please help us by checking off the card and returning to us?

KEY to functions performed by Bailey 700 Systems

A — Analog **A/D** — Analog and Digital
D — Digital **s** — sense and measure
d — display (indicate, record and/or log)
m — monitor (scan and alarm)
p — produce stored information for future use (tape, cards) **c**—compute **r**—control

● Installed ● On order

LOCATION	TYPE	FUNCTIONS
1. Chelan Co., Wash.	D	sdm
2. Chelan Co., Wash.	D	sd
3. San Francisco	A	sdc
4. Salinas, California	A	sdc
5. Los Angeles	A	sdc
6. Glendale, Ariz.	A	sdc
7. Alameda, N. M.	A	sdc
8. Amarillo, Texas	A/D	sdmc
9. Smithers Lake, Tex.	A	sdr
10. Orange Co., Tex.	A/D	sdmcr
11. Bronte, Tex.	D	sdm
12. Sioux Falls, S. D.	A	sdr
13. Oklahoma City	A	sdc
14. Harrah, Okla.	A	sdc
15. Muskogee, Okla.	A	sdc
16. Lafayette, La.	A	sdc
17. Jackson, Miss.	A	sdc
18. Cleveland, Miss.	A	sdc
19. Memphis, Tenn.	D	sdm
20. Paducah, Ky.	D	sdc
21. Sullivan, Ind.	A	sdc
22. Graham, W. Va.	A	sdc
23. Ashtabula, Ohio	A	sdc
24. Monroe, Mich.	A	sdcr
25. Rochester, N. Y.	A	sdc
26. Ludlowville, N. Y.	D	sdmp
27. Buchanan, N. Y.	A	sdr
28. Fairless Hills, Pa.	D	dm
29. Wilmington, Del.	D	dm
30. Washington, D. C.	D	dp
31. Hamilton Twp., N. J.	A	sdr
32. N. S. Savannah	A	sdr



BAILEY 700

ANALOG AND DIGITAL SYSTEMS IN ACTION

Installed or under construction, Bailey 700 Analog and Digital Systems are IN ACTION TODAY from coast to coast, providing integrated instrumentation systems accurately tailored to specific needs.

Note the variety of functions performed in these installations. Basic ingredients of all are electronic modules housed in standardized electrical cabinets, as shown here. This permits any combination of control, information or computing system elements to be combined and expanded as required to perform specific functions in individual installations. Wiring and maintenance is simplified —operator's console is freed of bulky equipment.

Ask your local Bailey engineer to arrange a visit and demonstration of a Bailey 700 System located near you, or at Cleveland. Or get IMMEDIATE details on the installation of greatest interest to you, by TWX—just jot down the number of the location you select on message form below and hand to your secretary. Reply will be transmitted at end of your message.

G153-2

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For name and IMMEDIATE details on installation of greatest interest to you, fill in number of location from map and have your TWX operator send this message:

WKLF 522

PLS SEND 700 SYSTEM DETAILS FOR LOCATION_____. PROCEED IMMEDIATELY WITH REPLY AT CONCLUSION OF THIS MESSAGE.

Name_____ Title_____

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Instruments and controls for power and process

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BAILEY METERS

By IGOR J. KARASSIK

Consulting Engineer and Manager of Planning, Harrison Div.

Worthington Corp.

The boiler feed pump and its associated equipment represent a major operating and maintenance consideration in today's power plant. Here we run in question and answer form a series of clinic sessions on various boiler feed pump problems. The replies are the work of one of the topmost pump authorities and give specific information which we hope will prove valuable to our readers.

Steam Power Plant Clinic—Part XXIII

QUESTION

Are variations of the available NPSH during transient conditions in an open feedwater cycle installation more critical for conventional or for high speed boiler feed pumps?

ANSWER

The problem is rather complex in that it includes far more variables and factors than appear in your question. It would be necessary to know some specific values applying to a particular installation. Various conditions might arise which could make one or the other type of pump more sensitive to NPSH variations. We can however, set down some general observations:

1. High speed pumps need greater NPSH values than conventional speed pumps. This is demonstrated by the relation of the suction specific speed (S) to the pump speed:

$$S = \frac{n\sqrt{Q}}{H_s^{3/4}}$$

where: n = pump speed, in rpm
Q = pump capacity, in gpm
H_s = required NPSH, in feet

Thus, for the same value of suction specific speed, the higher the pump speed, the higher the required NPSH. There is shown on Fig. 1 values of required NPSH for a range of capacities and of pump speeds. The chart is based on a suction specific speed value of 8000, which is a sound design value. Actually, where necessary, designs can be made to yield higher values of S up to 10,000 or even slightly higher. These designs, obviously require somewhat less NPSH for the same values of capacities and speeds than shown on Fig. 1.

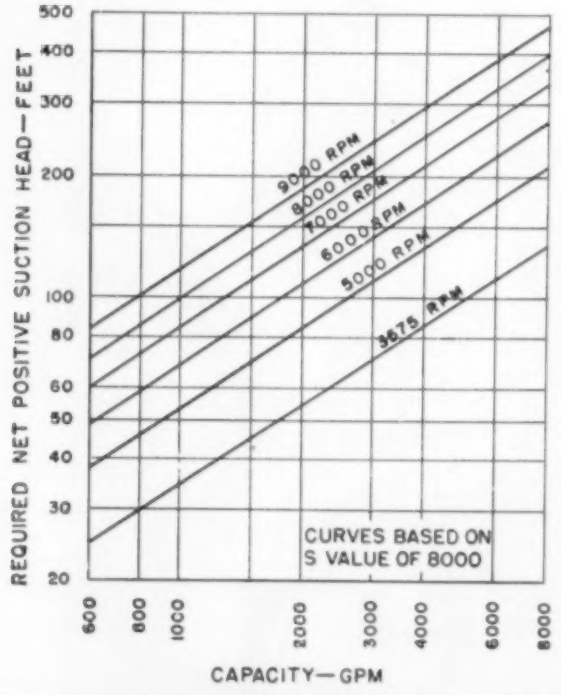


Fig. 1—Above curves demonstrate the higher the pump speed, the greater the required NPSH

2. High speed pumps can be designed for somewhat higher values of S than conventional pumps, by virtue of having a lesser percentage of the impeller eye area obstructed by the shaft.

3. The reduction in the available NPSH during transient operating conditions is independent of the type of pump involved. It depends solely on the volume of the deaerator storage and on differences in initial and final enthalpies of the condensate and the feedwater.

4. A given reduction in available NPSH is a lower percentage of the NPSH required for a high speed pump than of that for a conventional speed pump. For instance, let us assume that we are comparing two pumps A and B, such that:

Pump	A	B
Pump rpm	3600	7200
Required NPSH	40 ft	100 ft

Then a 4 feet reduction in available NPSH represents 10 per cent of the required value for pump A but only 4 per cent of that for pump B. But recall we are not speaking of like terms.

5. On the other hand, unless a booster pump is used, there will generally be more margin available for the conventional speed pump than for the high speed pump. For instance, in the case shown above the conventional pump may be installed with 30 feet margin (i.e., with 70 feet available under normal operating conditions) while the high speed pump may have only 10 or 15 ft margin (i.e., with 110 to 115 ft available NPSH). Under these conditions, a 15 ft drop in available NPSH during transient operating conditions would leave pump A undisturbed but may get pump B into trouble.

6. Generally, if the boiler feed pumps operate in an open feedwater cycle, booster pumps should and would be installed for high speed pumps. Under these conditions, then, the answer to your question would be that the reduction in available NPSH will be of less importance to a high speed pump installation than it would in the case of a conventional speed pump.

QUESTION

We have encountered some difficulties in holding the casing wearing rings of our boiler feed pumps in place. These are double casing barrel type pumps of two different designs. In one case, the wearing rings are pressed into the stage pieces separating consecutive stages and held to these stage pieces by bolts (see Fig. 2) which are peened in place. Another design of pump holds the wearing ring in place by a form of tack-welding to similar stage pieces. We have had some of the bolts back out after several years of operating in the case of the first design and the tack-welding fail in the other design. Couldn't these wearing rings be screwed into the stage pieces, eliminating the need of bolts or of tack-welding? As an alternate, couldn't they be mounted by means of some breech-block construction?

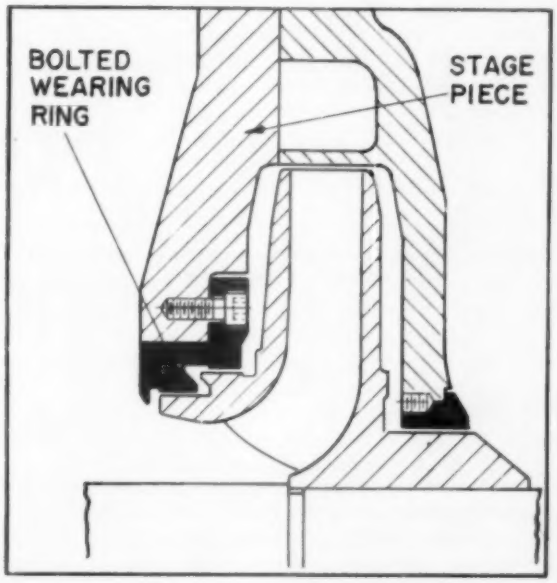


Fig. 2—One pump design in which wearing rings are pressed into the stage piece and held in place by bolts

ANSWER

It would be possible to screw the wearing rings into the stage pieces, but it would be quite difficult to hold reasonable concentricity between the bore of the casing wearing ring and the mating hub of the impeller. Furthermore, this mounting would still require some form of locking device, such as a set screw or a bolt.

A breech-block fastening is merely an interrupted thread, usually made as a heavy multiple thread to get a steeper helix angle, and somewhat adjusted so that the full length of each thread segment is in contact when the closing is seated. It is useful primarily for something which must be opened and closed quickly, such as the breech-block of a firearm. But it can only be half as strong as a full thread, since half the metal is cut away. I can see no advantage and many disadvantages of this as a wearing ring fastening.

If bolts are used to fasten the wearing ring to the stage piece, it is important that they be adequately peened in place at the time the pump is first assembled in the manufacturer's shops and that equal care be used in peening the bolts in place should the pump be dismantled and reassembled in the field.

Of course, some day the metallurgists will develop for us that "miracle" metal which will not wear, gall or seize under the particular conditions imposed by boiler feed service. We shall then be able to dispense with replaceable wearing rings and eliminate this fastening problem altogether. No doubt there will arise some new problem to tax our ingenuities, since there is no short cut to immortality for man-made machinery. Until the wearing ring does disappear, however, we shall just have to exert our efforts at taking proper care that it is adequately locked in place.

QUESTION

We are planning an installation of three boiler feed pumps, of which two are intended to run at full load and the third is a spare. Must each pump be provided with its own bypass recirculation line, pressure reducing orifice and bypass control valve or can a single common line, orifice and valve be used for the protection of the boiler feed pumps?

ANSWER

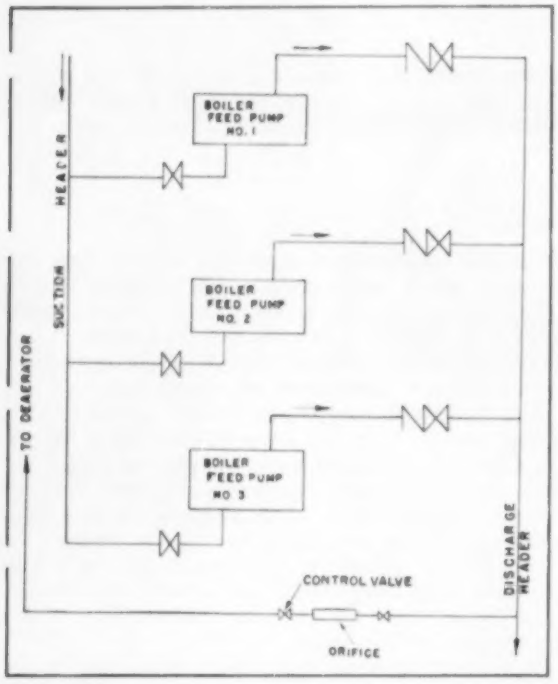
Decidedly, each pump requires its own recirculation line and controls. There are several reasons for this:

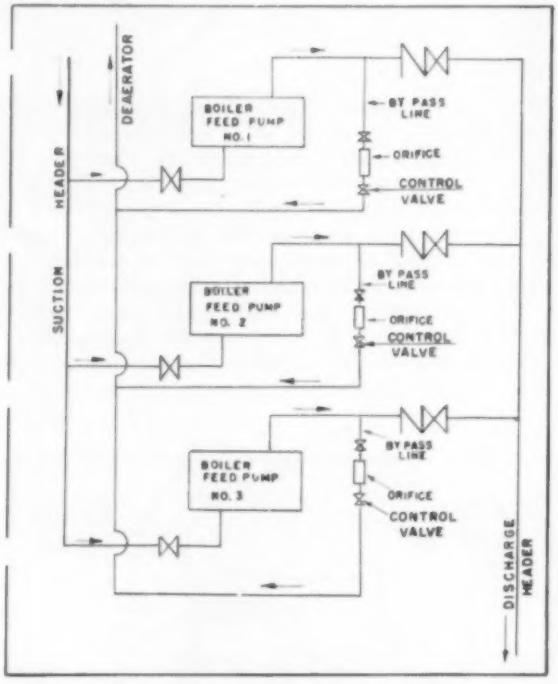
1. If a common recirculation system is used (as in Fig. 3), there arises the danger that when the flow is reduced nearly to the minimum, one of the two pumps operating may develop a slight excess of discharge pres-

sure and shut the check valve of the other pump, allowing it to run against a fully closed discharge with no bypass.

2. While two pumps normally operate to carry full load, there will be times when a single pump will be running at loads below 50 per cent. At other times, when switching pumps, all three pumps may be running for short periods. If the orifice capacity were selected to pass a flow equal to twice the minimum flow of a single pump, the recirculation would be twice that which is necessary whenever one pump would be running alone and only two-thirds of that required whenever all three pumps would be on the line. The first is wasteful and the third does not afford the necessary protection.

Separate bypass recirculation lines should be provided, originating between the pumps and their check valves, as shown on Fig. 4. Each line must have its own orifice and its own control valve. Of course, these individual lines can be manifolded into a single return header to the deaerator, on the downstream side of the pressure reducing orifices and control valves.





Figs. 3 and 4—Common recirculation system for three pumps without separate bypass lines for each pump, left, is asking for possible operating troubles from differences in individual pump discharge pressures. Fig. 4, right, offers a good solution

MHD—Progress Report

Back in November of 1959 the Avco Corp., together with ten supporting utility companies, announced the sponsorship of a research program on MHD—Magneto-hydrodynamics—wherein a stream of high temperature ionized gas called a plasma is put through a magnetic field to generate electricity. On March 13 of this year this group gave a progress report and announced the addition of two more sponsoring utilities, the Boston Edison Co. and the United Illuminating Co.

In the experimental MHD generator, named the Mark II, the hot plasma is provided by a combustion chamber, somewhat similar to a rocket thrust chamber. The combustion chamber burns kerosene or alcohol and gaseous oxygen, "seeded" with powdered potassium salts to make the plasma an electrical conductor. The combustion chamber runs at about two atmospheres' pressure, and burns about four pounds of mixture per second. The plasma leaves the combustion chamber and enters the generator channel at a temperature of about 5000 F.

The magnet for the generator consists of 22 tons of copper; the iron pole pieces weigh 25 tons. A battery bank is used to excite the magnet to a maximum field strength of 32,000 gauss. The active gap in the magnet is 8-in. × 24-in. × 5 ft long.

The Mark II MHD generator is designed for runs of up to one minute, which is more than adequate for studies of fluid mechanics. Long duration tests of generator components will be conducted on a smaller scale.

As originally conceived, the first practical MHD power plants would require a regenerator to preheat the air that would be fed into the combustion chamber. It was thought necessary to preheat the air to about 3600 F, to obtain sufficient temperature in the combustion chamber. In the combustion chamber, the air would be

mixed with a fossil fuel (coal, oil or gas) and burned to create the approximately 5300 F plasma that flows through the MHD generator channel.

While it is considered technically possible to develop a regenerator to run at about 3600 F, the problem is a difficult one, especially from a materials point of view. However, during the past year, researchers hit upon the oxygen cycle as a means of easing this problem.

Fundamentally, the reason for preheating the air in the generator was to make the molecules in the air more energetic. This leads to higher temperature in the combustion chamber. But air is only 20 per cent oxygen; the remaining 80 per cent is almost entirely nitrogen, with traces of carbon dioxide, water vapor, argon and other inert gases. Much of the heat energy of combustion is used to heat these molecules, which do not participate in the combustion. Thus, the combustion temperature is low unless the air is preheated.

It was determined, then, that air enriched with extra oxygen would allow lower running temperatures in the regenerator, while still giving high temperature in the combustion chamber. So current plans call for adding an oxygen plant to the MHD generator system. The enriched air reaching the combustion chamber will probably be about 30 to 50 per cent oxygen with the usual traces of the other gases.

The inclusion of the oxygen plant appears to result in a slight increase in capital cost and also a slight increase in heat rate. It is felt that these effects are outweighed by the practicality achieved by the use of the oxygen cycle.

The oxygen cycle means that the regenerator can operate at lower temperatures. Regenerators now in commercial use can be employed in the MHD system. This means that it will not be necessary to develop special materials and design a new regenerator. And oxygen plants similar to the type required for the MHD system are already in operation elsewhere.

Thus, all the "auxiliary" components of the MHD power plant can now be considered "off-the-shelf" items. Further developments and improvements may be desirable, but existing equipment can be used in a working MHD power plant. Only the generator itself requires further development.

While research and engineering work has been in progress during the past year, the economic feasibility of the MHD power plant has also received constant scrutiny. The developments of the past year have reinforced earlier conclusions that the MHD system can give greater efficiencies at capital costs competitive with conventional power plants.

The MHD system promises more electrical energy per unit of heat (more kilowatt hours per Btu). The first MHD power plants, its developers believe, could be as much as 40 per cent more efficient than existing electric power plants *at the outset.*

Editor's Note: On pages 17 and 18 we have inserted a post card on which we ask you to give us your reactions to the articles in this magazine. Will you please help us by checking off the card and returning to us?

SURPLUS PIPE & VIBRATORS FOR SALE

12′ 4″ XXH Chrome moly pipe, ASTM, A-335, P22, 2.1/4% Chrome, 1% molybdenum, plain ends.

306′ 6″ XXH Chrome moly pipe, ASTM, A-335, P22, 2.1/4% Chrome, 1% molybdenum, plain ends.

34′ 8″ sch. 160 seamless pipe, grade "B", ASTM, A 106 plain ends.

228′ 8″ sch. 40 carbon, 1/2% moly pipe, ASTM, A-335, PL, plain ends.

36′ 8″ sch. 60 chrome moly pipe, ASTM, A-335, P22, 2.1/4% chrome, 1% molybdenum, plain ends.

139′ 10.5″ O.D. 1.25″ minimum wall, 2.1/4% chrome, 1% molybdenum, alloy steel pipe, ASTM, A-335, grade P-22, plain ends.

27′ 10.75 O.D. sch. 60 chrome moly pipe, ASTM, A-335 P-22, 2.1/4% chrome, 1% molybdenum, plain ends.

70′ 12″ sch. 160 seamless pipe, grade "B", ASTM, A 106 plain ends.

53′ 18″ .750 wall chrome moly pipe, ASTM, A-335, P22, 2.1/4% chrome, 1% molybdenum, plain ends.

401′ 18″ O.D. 1″ min. wall, 1 1/8″ nominal wall thickness, 15 5/8″ min. I.D. chrome, moly pipe, ASTM, A-335, P-22, 2.1/4% chrome, 1% molybdenum, plain ends.

Penflex M-100 stainless steel No. 15 flexible metal tubing with 150 lbs. ASA std. Tite-pak flanges attached each end in diameters and lengths as follows:

2–8′	5-3/16″ x 10″ diam.
6–8′	4-9/16″ x 4″ diam.
12–3′	11/16″ x 4″ diam.
5–4′	x 10″ diam.
4–2′	5-3/8″ x 3″ diam.
4–5′	1-3/8″ x 6″ diam.
8–3′	11-1/16″ x 8″ diam.
4–2′	6-13/16″ x 8″ diam.
4–3′	11/16″ x 6″ diam.
5–4′	1-3/16″ x 10″ diam.

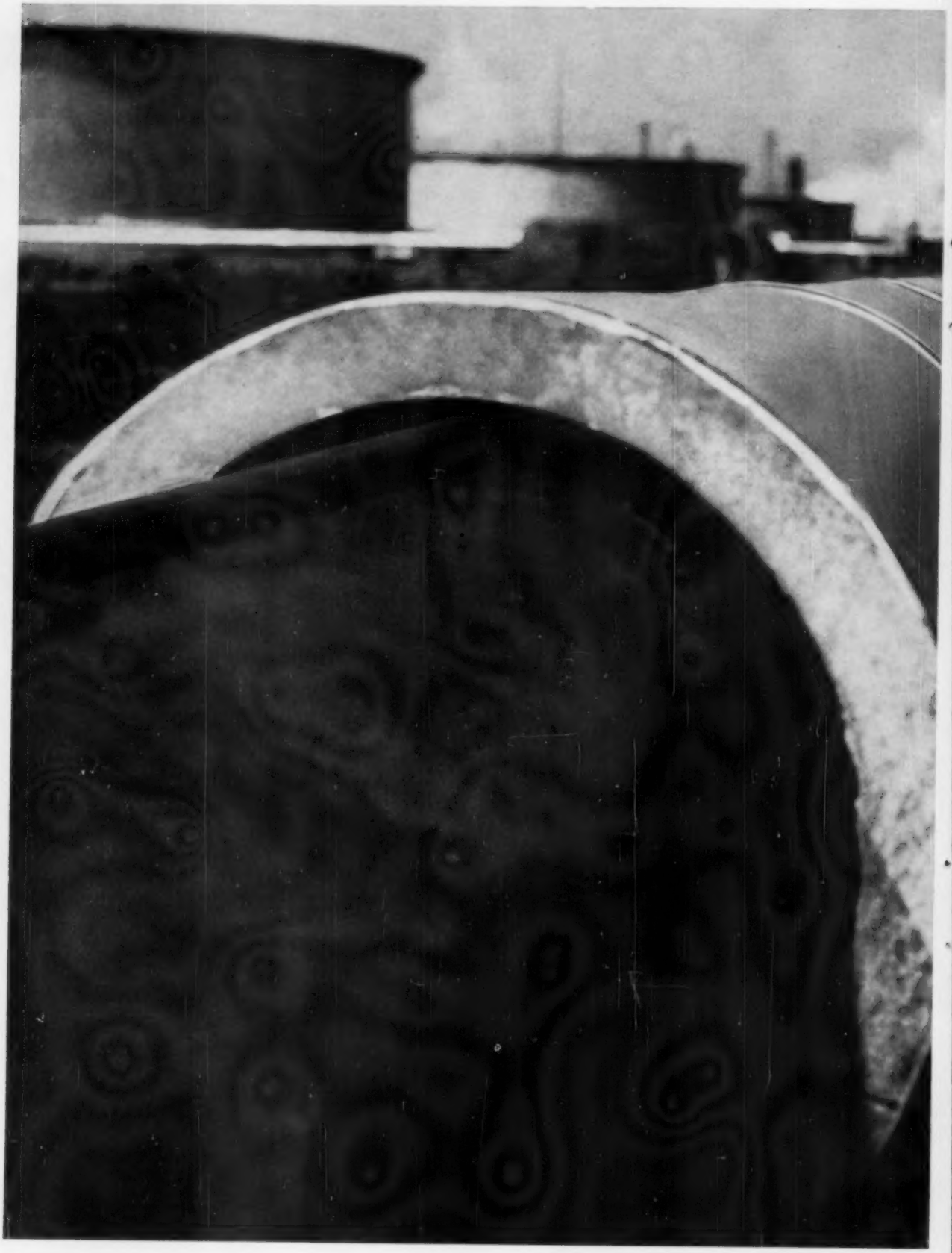
41 G.E.C. Sherwin immersion type MS2B bunker vibrators.

THE ABOVE MATERIAL IS ATTRACTIVELY PRICED FOR QUICK SALE

For further information and particulars contact the Disposal Supervisor, BElmont 1-4111, local 2-8753, Surplus Equipment and Materials Department, Ontario Hydro, P.O. Box 905, Kipling Avenue, Toronto 18, Ontario, Canada.

All subject to prior sale.

ONTARIO HYDRO



Oval "overcoat" for a problem pipeline

J-M METAL-ON
in "long-legged" form cut insulation costs for Shell Oil

A piggy-back steam tracer line made insulating asphalt pipelines at Shell Oil's Norco, La., plant a problem. Every foot of pipeline—if insulated in standard fashion—would have required insulation a size larger than normal. And there were miles of pipe involved.

Johns-Manville and its contract unit in New Orleans, McCarty-Branton, Inc., studied the problem and made an unusual recommendation. They suggested using elliptically shaped, "long-legged" Metal-On®, the aluminum-jacketed pipe insulation. This oval shaped pipe covering fit right over the asphalt pipes and the troublesome tracer line—and saved substantially in the cost of insulation.

Typically, Johns-Manville had the answer for this insulation problem. *Your* insulation jobs, too, will be solved best by Johns-Manville. For further information, write to J. B. Jobe, Vice-President, Johns-Manville, Box 14, New York 16, N. Y. In Canada, address Port Credit, Ontario. Worldwide, cable Johnmanvil.

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AN INSULATION FOR EVERY COMMERCIAL AND INDUSTRIAL USE

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Close-up of line section showing steam supply line and ½" copper tube tracer atop main line before it is coated with material used to bond it to main pipeline.

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Please send me a sample of Metal-On

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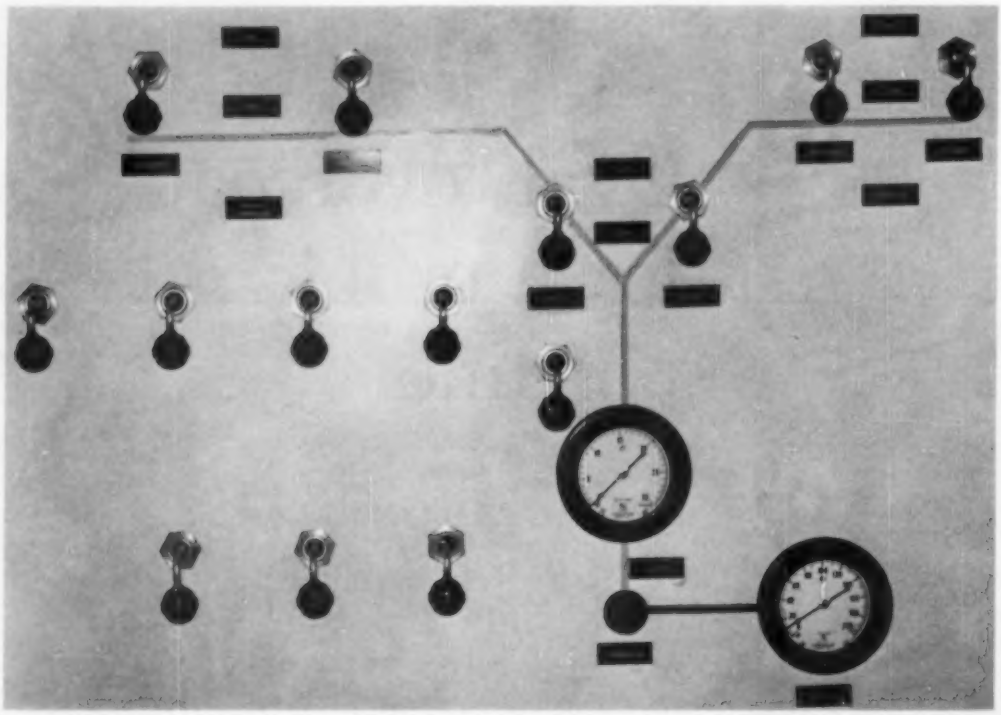
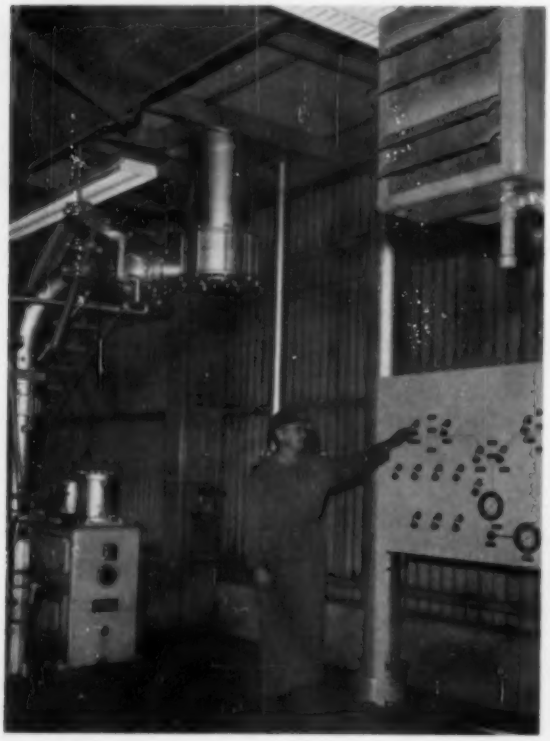


Control Panel

1. The complete system is operated from this panel. Three-way air valves open and close valves in the pneumatic material handling system. A vacuum gage is provided to determine when hoppers are empty. The untagged valves are for a future extension of the system

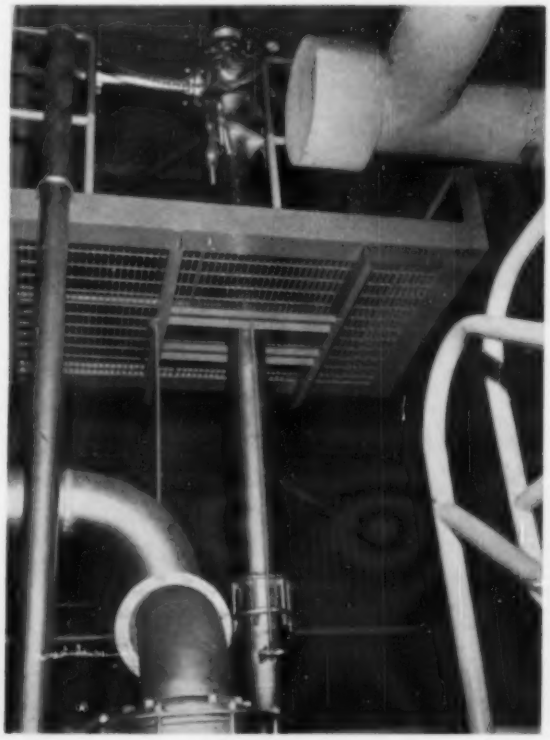
Control Panel & Air Separator Tank

2. Adjacent to the control panel is the bottom half of the air separator tank. This tank is vented and provides a means of removing the carrying air from the system



Water Jet Exhauster

3. At the top of the picture is a water jet exhauster which provides the vacuum source for the system. It uses about 700 gpm of water to help transport 10 tons of gas per hour



A former divided fly ash removal system proved a serious handling problem. Here is a short, to-the-point story on one way out of a typical power problem.

By R. G. James*

General Electric Company

Pneumatic Material Handling System Solves Difficult Fly Ash Disposal Problem

INSTALLATION of a pneumatic material handling system has improved the method of fly ash disposal at the Atomic Energy Commission, 300 Area, steam generation plant, located near Richland, Washington. The steam generation plant is part of Hanford Atomic Products Operation which is being operated for the government by General Electric Company.

Process and heating steam for the 300 Area is produced by six, coal-fired, spreader-stoker boilers. All boiler flue gas is passed through one of three mechanical fly ash separators before being discharged to atmosphere.

Before the new system was installed, fly ash from five existing boilers was collected by two separators. One separator discharged fly ash by gravity into the base of a 150 ft brick stack. The other separator also discharged fly ash into the stack by means of a reinjection nozzle and blower combination, which transferred the fly ash 85 ft through a 4 inch pipe to the stack. Periodically, fly ash was removed from the stack base by a sluicing operation that washed the fly ash down a trench to an ash pump pit. From here the fly ash and water mixture was pumped 900 ft to a disposal pond outside the area.

This system was unsatisfactory because not enough force was available for removing fly ash from the separator hoppers. As a result, the hopper discharge openings were frequently plugged, fly ash filled the hoppers and the separators were put out of service. Furthermore, when the stack base was sluiced, the ash pump had to be operated. This required the services of two men and 1800 gpm of water.

The basic pneumatic handling system was installed with a new fly-ash separator 18 months ago, when the sixth boiler was added to the plant. Since that time, the system has been modified and extended so that it is now used for removing fly ash from all separators. Each separator hopper discharge opening is equipped with a remote-manual material handling valve. Piping consists of a 4 in. material with the trade name of Ashcolite. There are two branch lines in the system, each being equipped with a remote-manual segregation valve which reduces system leakage when a particular branch line is not in service. A water jet exhauster is used to create the necessary vacuum for producing air flow to convey fly ash through the transport piping. The fly ash and water mixture discharged from the Hydrovactor passes through an air separator tank and then flows to the disposal pond. One man operates the entire system from a centrally located control panel.

Each material handling valve and segregation valve is opened and closed with a three-way air valve mounted on the control panel. With the air valve in the open position, 100 psig compressed air is admitted to the material handling valve or segregation valve actuating air cylinder. One separator hopper is emptied at a time. A control panel mounted vacuum gage indicates when the hoppers are empty. With all hopper valves closed, the vacuum in the system is about 25 in. of Hg. When a hopper is being discharged, the vacuum is about 6 in. of Hg. and it drops to zero when the hopper is empty.

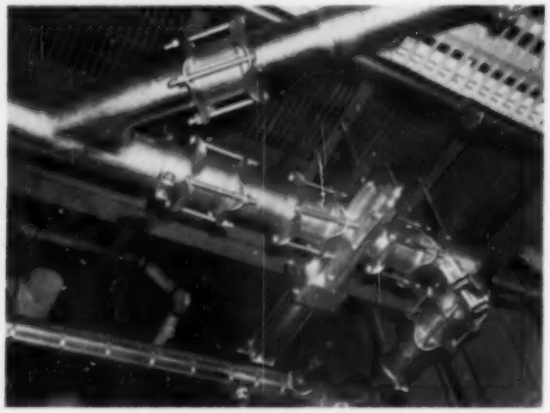
The water jet exhauster uses about 700 gpm of water and the system transports fly ash at the rate of 10 tons per hour.

* Engineer—Plant Facilities, Hanford Atomic Products Operation, Fuels Preparation Department.

This pneumatic handling system has reduced water consumption and saved manpower. In addition, it has contributed to the reduction of the quantity of residual fly ash that is emitted from the steam generation plant because of the more efficient removal of fly ash from separator hoppers.

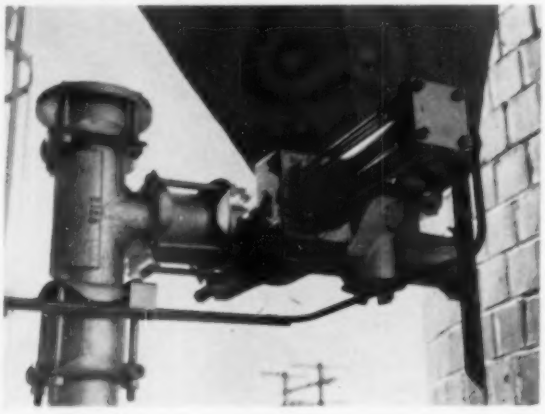
Segregation Valve

4. One segregation valve is installed in each branch line to reduce system leakage when the particular line is not in use. Compressed air at 100 psig is admitted to operate the air cylinders.



Material Handling Valve

5. Each fly ash hopper is equipped with a valve of this type. When these valves are in service, they admit carrying air into the system which transfers the fly ash to the Hydrovactor.



Looking Back at Management

By H. G. EBDON

President, Combustion Engineering, Inc.

As the feature speaker at the All Engineers' Dinner at the American Power Conference, Mr. Ebdon set his audience to contemplating the competitive position of American industry. As a background he raised the question, "How far have we come in the 15-year post-war period? The work force has gone from 53 to almost 70 million with a shorter work week plus innumerable coffee breaks, extended vacations, additional holidays and tempting unemployment pay. Population is up from 140 million to 182 million; Gross National Product, from 213 billion to 500 billion dollars; installed electrical capacity, from 50 million to 175 million kw; and electrical generation, from 225 billion to 750 billion kwhr.

"These figures of growth indicate that we did a big job, but did we do it *well*? If we had, why are we facing the situation that exists today? Well, in the first place, the industrial rehabilitation of our allies is complete, paid for mostly by Uncle Sam. That market has now dried up. In fact, we did that job so well we are finding it most difficult to compete with them in world trade. Many of us pull our hair and shout, "What can you expect with the differential that exists in the labor rates?" We all know the average hourly wage in the steel industry has gone up from $1.25 to $3.75, plus 41 cents fringe benefits since the end of the war, but we also know that American productive workers, at least the greatest percentage, who have a desire to work, can outproduce their foreign counterparts. Production wage rates, however, are only *part* of the overall costs, as you will see.

"I have used the term 'productive worker' a number of times, Mr. Ebdon went on to say, to distinguish him from the 'non-productive worker' who, as overhead, is also part of the product cost. By non-productive worker I mean all indirect labor from clerk to top management.

"I think we paid far too little attention to this kind of overhead. We became preoccupied with direct labor costs and fringe benefits but overlooked indirect labor, for which we had—wittingly or unwittingly—gained a new affinity. Thus American industry became overmanaged. We reached the point where we had assistant vice presidents, assistant managers, assistant supervisors, all of whom had to have assistants of their own, clogging communications and building up unnecessary paper work. Dr. Parkinson finally isolated the virus causing our affliction and found that the number of workers and the quantity of the work are not related to each other at all, and the rise in the total of those employed would be much the same whether the volume of the work were to increase, diminish or even to disappear.

"Heretofore, many thought that this new form of Parkinson's disease had been confined to governmental bureaucracy, but through soft working habits both labor and management have succumbed in private industry.

"An illustration of the dangers inherent in overmanagement was given by Cameron Hawley in the February issue of *Reader's Digest*. First he cites the words of an American businessman who made these comments following a visit to a European firm with which his company had a manufacturing agreement: " 'Until I got on the inside . . . I thought they had us licked over here because of wage rates. I know differently now. For every penny they're saving in direct labor costs, they've got us whipped by three cents in general overhead. Inside the plant, it's about a standoff—but when you get to the office, they make us look like fools.' "

American Power Conference in Review—I

The twenty second annual meeting of the American power Conference was again held at the Sherman Hotel in Chicago, March 21-23, inclusive. Registration was excellent again with about 3000 in attendance.

The Avon Station

Engineers from the Cleveland Electric Illuminating Co., the Westinghouse Electric Corp. and Combustion Engineering, Inc., combined forces to give a rounded discussion of the Avon No. 8 power plant.

Neal F. Gill and **Newton D. Flack,** The Cleveland Electric Illuminating Co., were joint authors of the opening paper, "Initial Operation of Avon No. 8, A Supercritical Plant," covering the first year's operating experience with the 250 Mw, 3500 psi, 1100 F unit.

Between initial operation and the December 23, 1960, outage, a period covering one year and five days, the Avon No. 8 Unit generated 1,233,694 Mwhr or at a capacity use factor of 54.2 per cent. The availability factor was 71.2 per cent. The longest time the unit was on the line without being shut down was from August 1, 1960, to October 24, 1960, a period of 54 days. There were a total of 21 outages experienced during the first year.

Turbine difficulties caused five outages ranging from 14 to 784 hours' duration. The turbine was available for service 91.4 per cent of the time. Incidents attributable to the boiler caused 13 outages ranging from 3 to 856 hours in length. The boiler was available 80.0 per cent of the time. There were three machine service outages due to other equipment failure ranging from four to nine hours' duration which gave an availability factor of 99.8 per cent.

The Avon No. 8 Unit was tripped 14 times for other-than-scheduled reasons. It is interesting to note that only one of the 14 trips was manual. This is, in some respect, an indication of the degree of automation of the Avon No. 8 Unit. The causes of the 14 trips are: boiler tube failures—3, false or accidental reasons—5, malfunctioning of boiler feed pump governor—2, combustion control equipment malfunctions—2, operator's errors—2.

The first-year availability record of this supercritical-pressure unit is not too discouraging. In fact, it was as good as the 2400-lb psi Ashtabuia No. 5 Unit which was, at the last minute, scheduled ahead of Avon No. 8 to provide reliable capacity. However, the long-term reliability of the supercritical design remains to be proved.

Over half of the boiler outages were caused by tube failures some of which were due to improper shop welds. The longer outages were a result of overheating the tube metals.

One of these outages was due to the overriding effect of natural circulation on the forced circulation. This occurred in a spacer tube in the reheater platen. The heat effect at low loads evidently was great enough to reverse the flow. When the flow direction started to return to normal at the higher firing rates a period of stagnation occurred and the tube overheated and failed. This required a change to provide positive upward flow at all times. The unit was out one month for this change.

A delay in going into service rather than a credited outage occurred when steam formed in the waterwalls causing some 60 tubes to bow out, and swell although only one failed. Subsequent strict adherence to the procedure requiring the boiler pressure to be above the saturation temperature at all times has been effective and no doubt prevented at least one outage from this cause.

Overfiring can also cause tube overheating and was responsible for one of the longer outages. In going from manual to automatic to manual control, fuel feed was inadvertently raised to the 240 Mw level while water flow was only sufficient for 150 Mw. While this was an operational error in that the operator failed to balance his controls, it does indicate the strict need to keep water flow and fuel feed in balance at all times, and the desirability of a control to insure this. A protective feature will be added to the automatic control as a result.

It was found that moderate overfiring can also occur whenever the firing rate is increased. The reason is that there is a large time lag before the thermostat at the transient section signals for increased water. An anticipating device, prompted by any increase in coal flow, will be installed to quickly change water flow in the right direction. With these several changes it is hoped that

any overfiring of fuel will be controlled and prevent further tube burn-outs.

In general, the many Sulzer control valves have performed well and require little attention. The packing for the seat hold-down device where it penetrates the valve body was troublesome in the case of the boiler stop and superpressure by-pass valves. A new design will be incorporated as soon as possible.

Soon after the turbo-generator was phased-in a steam leak developed in the horizontal joint of the outer cylinder of the high pressure turbine. During the present outage the upper cylinder flange in the area of the bolt holes has been grooved so as to increase the unit pressure on the flange while maintaining the same force on the turbine flange bolts.

From the beginning erratic operation of the control cable operated valve limit switches on the turbine stop and control valves was experienced. This persisted until the limit switches were located directly on the turbine stop and control valve servo motors. This improved the limit switch operation but did not entirely solve the problem. A new type limit switch is now being tried.

At certain loads main turbine governor valves had a tendency to oscillate. This, in turn, adversely affected pressure control and overall combustion control.

A problem that caused more worry than trouble was the initial galling of the main steam control and stop valve stems. Design changes and repairs to the valve internals resulted.

The original design of the boiler feed pump turbine drive turning gear incorporated a solenoid operated sliding clutch jaw arrangement. During initial operation, the turning gear would suddenly disengage. It was found that the flow of warm-up water supplied by the booster pump caused the boiler feed pump to turn faster than the turning gear speed. After the turning gear disengaged the boiler feed pump would stop occasionally. This turning gear problem was solved by replacing the turning gear solenoid operated sliding gear arrangement with an overriding clutch.

A difficulty that required long, hard and extensive debugging was due to the flyball governor control system which was designed specifically for the motor driven boiler feedpump. The main purpose of the governor control is to permit the motor driven pump to be operated in parallel with a steam turbine driven pump.

The one major problem of this control system was due to the design of the oil reservoir which was common with the boiler feed pump step-up gear. The apparent trouble was air entrainment in the oil coupled with a small oil reservoir which had insufficient retention time to ride the oil of air. This air in the oil caused instability and erratic operation of the governor. Installing a separate governor oil reservoir with a longer oil retention time appears to have solved this problem.

Difficulties were encountered with the system which controls the governors of the boiler feed pump turbine. The Cellulube 220 fluid in the Sulzer system was apparently incompatible with the material in the diaphragm-operated solenoid valves and pressure switches. A change to metal bellow-type equipment solved the problems. No material trouble was experienced with the turbine conventional flyball governor which operated on a petroleum base lubricating oil.

The high-speed boiler feed pumps have performed as designed, and have operated essentially without incident for one year. During the early stages of operation, however, trouble was encountered with the water injection seal due primarily to dirt in the condensate injection lines.

All seal lines had been flushed prior to use, and condensate supply was filtered to remove suspended solids as small as five microns. As it turned out, this was not adequate, and the water picked up dirt in the supply lines to the seals which had not been carried out by the initial flush. The solution to the problem was to put individual filters in the lines as close as possible to the seals. It is now felt that start-up seals which would have greater clearances than the normal operating seals should be used on initial startup. Once the system has been cleaned, the actual close clearance seals could be installed for more efficient operation.

The majority of seal difficulties was concentrated at the outboard end of the pumps. After replacing three of these outboard seals, it was determined that the packing at the inner end of the shaft sleeve was not capable of holding the pressure on the high-pressure end of the balancing disk. A leak would develop in a few weeks between the balancing device and the shaft, and under the adjacent shaft sleeve. The design change by the manufacturer eliminated this leakage under the shaft sleeves.

The turbine by-pass system, unique to the supercritical plant, is subjected to rather severe service. It must receive steam and water at pressures of 3500 psi and discharge it at condenser vacuum.

During the initial operation of the boiler through the by-pass system, extreme vibrations were experienced in the system. This vibration loosened many of the flange joints, equipment hold-down bolts and valve bonnets, and also caused failure of vent connections on both the water separator and injection condensate cooler (steam killer), and thermocouple wells located in the low pressure by-pass system. A major portion of this initial vibration was caused by faulty operation of the steam killers. It was found that the initial vibration had actually broken the water nozzles located in this steam killer, which, in turn, increased the vibration to an even higher level. By redesigning and strengthening the injection condensate nozzles, the vibration in the by-pass system was reduced.

In general the authors stated that, "We have had more trouble than we wished, but less than we expected." The authors then began to explain some of the complications they faced. For example, points that are monitored to give maximum safety and flexibility of operation are: 150 pressures, 350 temperatures, 150 alarm points, 50 drive and control unit positions, 50 control valves, 50 others, such as levels, flows, turbine thrust loads.

Primary checking out, calibrating and debugging of instruments, controls and interlocks took about three months prior to start-up and approximately three months during initial operation. Changes in the control system are, of course, still going on to suit changes in operation procedures and major equipment design as more operating experiences are obtained. To date, the control room is being operated by two men. Another year of experience will probably be required before any attempt to operate this unit with only one man in the control room.

Additional men are presently being used during a cold start. To date, there has been no reason why this could not be started with the four men that now operate it.

A complete starting procedure was written for starting the unit up from a cold condition. This procedure is very detailed and it is hoped on subsequent starts that improvements will be made by the operating people. The complexity of starting plus the hundreds of sequential operations makes it mandatory that the operator follow this procedure step-by-step to insure safety of equipment and men.

One of the greatest problems was the training of operators for this supercritical unit. This was the largest single-step change ever taken by operating personnel in the authors' company.

One item of control that is of significance is that this unit has been shut down many times under normal conditions or emergency conditions with little or no help from the operator and, to date, with no damage done. There are 17 different automatic methods of tripping this unit. Of these, 12 are for turbine-boiler protection, and five for generator protection. To date, it has been proved under actual operating conditions that four of the 12 methods for protecting the turbine-boiler work. In addition, the generator protection system has been used once under controlled trip test conditions.

Following the inspection of the boiler and turbine, it became immediately apparent that the one singular chemical characteristic which could easily jeopardize the efficient operation of this unit was copper. It definitely appears to be a deposition phenomena especially characteristic of supercritical pressure conditions. Turbine blade deposits showed presence of both zinc and nickel, so it appears the source of the copper could be the antimonic admiralty condenser tubes, low pressure heater admiralty, the high pressure heater monel tubes, or any combination of the three.

J. I. Argersinger and **Gordon C. Smith** of Combustion Engineering, Inc., then offered the details on "Supercritical Boiler Operating Experience at Avon No. 8." One of the unusual features of boiler design occasioned by the once-through principle is the use of a varying design pressure in the primary circuits of the boiler. Starting with 3500 psig throttle pressure as a base, pressure drops for full load conditions were calculated for the steam piping, valves, superheater sections, water wall, economizer, and feedwater piping. This established a "maximum operating pressure" line through the unit. The pressure drop calculations included a margin to insure that actual operating pressure in any part of the unit would never exceed the expected pressure and thus constitute a limitation to the capacity of the unit. An additional margin of 175 psi (5 per cent of throttle pressure) was added to establish the "minimum design pressure" line throughout the boiler and piping. Tubing and piping were then selected in commercial thicknesses to provide a stepped line of "maximum allowable working pressure" above the minimum design line. Test results have demonstrated the adequacy of the design.

The farthest departure from conventional boiler construction occurs in the furnace enclosure, which consists of tubes operating at varying individual temperatures. The boiler designer has two basic choices in handling this situation. He can provide for individual movement of each tube so that it can expand according to its temperature; or he can attach all the tubes together, as by continuous welding, and thereby constrain each tube to expand in accordance with the average temperature of the group. For all of our first round of monotube units we chose the former method, providing for individual expansion. Following some detail modifications, this method has proved satisfactory in operation. No basic problems have arisen and the approach is technically sound. Unfortunately, the execution is expensive, and requires relatively elaborate support construction.

In the enclosure of the rear pass, where temperature differences were expected to be more moderate the alternate solution was used and restrained the tubes so that they could expand only as a group. This construction has also proved 100 per cent satisfactory in operation. This experience, backed up by extensive model tests and analytical work, has brought the authors to the conclusion that, for C-E's next supercritical unit, the most satisfactory and economic furnace enclosure would be of continuously welded tubes and bars, of the type introduced so successfully at Kearny some ten years ago.

Steam temperature regulation is of the utmost importance in boiler and turbine operation, and especially so when working at a supercritical pressure. It is not enough to apply control hardware. The proper features must be incorporated in the boiler design. At Avon, the primary water heating and superheating surfaces of the unit are divided into four basic circuits, two per furnace. The superheater sections are subdivided into eight circuits. Each circuit has its independent flow and temperature controls. The separate control in each quarter furnace, combined with two stages of desuperheating, provides uniformity of temperature across the width of the unit. Element temperature traverses were illustrated by heavy black lines superimposed on blocks and the temperature of the eight superheater leads were also shown, with a deviation of about plus or minus 3 degrees from average.

Reheat temperature is controlled by burner tilt, which, of course, does not operate selectively on the four quarters of the furnace width. In this case the uniformity of the outlet element traverse is the result of (1) pressure equalization halfway through the reheater, (2) gas distribution and (3) criss-crossing of the connecting links between furnaces.

Not only the lateral temperature distribution, but also the average temperature rise in each section of the unit is of concern to the designer and the operator of a once-through boiler. Only a few years ago there was a veil of mystery surrounding the properties of supercritical water and steam. People were concerned about whether there was such a thing as steam at supercritical pressure, and some writers cast doubt on the engineer's knowledge of heat transfer in this region. The authors then produced a set of curves to compare the predicted and actual temperature rise in the Avon unit, in the various components of the boiler primary circuits and the reheater. The close agreement, the authors felt, dispels and doubts about engineering competence in heat transfer in the supercritical fluid.

One of the problems that was foreseen is the necessity of avoiding steaming at subcritical pressure in a unit

which is not designed to handle a two phase mixture of water and steam in the furnace walls. This problem or requirement has to be borne in mind during startup, and operating procedures were carefully planned to prevent any possibility of boiling. Unfortunately, during the early operation at Avon, startup was authorized without establishing the required 30 per cent minimum flow and without maintaining a sufficiently high pressure. This was done in an ill-advised effort to conserve fuel and energy during the startup. As a result, steam was formed in several water-wall tubes, and the flow in these tubes was reduced to the point that overheating produced one tube rupture and a considerable amount of bowing. The operating procedures required to avoid this trouble are simple but extremely important.

Uniform distribution of flow through parallel tubes in a supercritical unit is generally easier to obtain than in the evaporating section of a subcritical unit, but it is not automatic. Along with proper operating procedures, the proper design features must be present. At Avon and at Eddystone Unit No. 2 during startup and light load operation, the distribution in the waterwalls was inadequate while the unit was being overfired for the purpose of raising temperature or picking up load. The result was low flow and excessive temperature in a few tubes, which led to tube ruptures on two occasions at Eddystone. The problem was corrected by installing orifices at the waterwall tube inlets. This was done at Eddystone early in December and has proved effective in maintaining proper distribution and a narrow band of waterwall tube outlet temperatures. The same change has just been completed at Avon and during the start up about ten days ago, the effect appeared to be equally satisfactory.

Another problem occurred in the water cooled spacer tubes which are used to maintain alignment of superheater and reheater elements. At Avon, during start up, the tendency for natural circulation was strong enough to produce reverse flow. This was corrected by rerouting the spacer, so that the natural circulation aided rather than opposed the desired flow. No further trouble has been experienced.

Under steady state conditions the temperatures leaving the transition section provides close coordination of feedwater flow and firing. Under changing conditions, however, the transport lags in the boiler and the sensing lags in temperature measurement make it impossible to adequately regulate feedwater from temperature alone. Some type of anticipation signal is required. Originally this was provided in the form of the pressure drop across a steam flow nozzle located in the transition outlet link pipe to pick up any change in firing rate or furnace heat absorption. The arrangement works very well on a subcritical unit, but it proved entirely unsatisfactory in the supercritical units. A direct signal indicating totalized fuel feeder position has now been introduced as anticipation for the feedwater control.

C. C. Franck, Sr., and **J. A. Carlson,** Westinghouse Electric Corp., then discussed the "Avon Superpressure Steam Turbine Generator Unit." Among the numerous problems imposed by the design premises, one relates to the relatively small volumetric steam flow at the super pressure turbine inlet stage and another is concerned with the relatively large volumetric flow at the exhaust stage. In spite of the fact that 39 per cent of the admitted steam is extracted at intermediate points for feed heating and boiler feed pump drive purposes, the ratio of the terminal to the exhaust volumetric flow is over 1600 fold. A triple exhaust low pressure section with 25-in. last row blades was selected for optimum leaving loss conditions.

One design reached, from design studies of a previous unit, was to split into two elements the expansion of steam from the main inlet pressure to the reheat pressure level to secure the smallest practicable turbine element which would be subjected to steam pressure and temperature beyond the limit of existing operating experience for ferritic materials. This decision aggravated the problem of shaft seals.

The first stage of the superpressure turbine element is designed for complete admission at all loads. With a temperature of 1100 F at the inlet, the resultant throttling will result in a temperature of 980 F. In other words, there will be an instantaneous drop of 120 F as a result of such operation. Secondly, the loading of the first row of blading is also affected by sectional valve operation. For example, under normal conditions, the blade loading of the first rotating row is equal to 117 kw per blade, but on the assumption of two quadrants closed and two quadrants open, this load would increase to 366 kw per blade.

Another important consideration resulting from partial admission operation is the resultant force on the spindle which would cause the shaft to deflect. Under conditions of complete admission, forces are balanced and there is no shaft deflection. However, with two adjacent nozzle quadrants closed and two adjacent quadrants open, the partial admission forces would be approximately 37,000 lb. This would result in a shaft deflection of 0.062 in., which would make it impossible to maintain reasonable radical clearances between the rotating and stationary parts. As a result, all governor valves are arranged to operate in unison.

Within the past year, a new alloy, Nivco, has been made available commercially. This alloy was developed specifically for high temperature blading applications and possesses high damping, high tensile and superior creep resistant properties at elevated temperatures. The application of this new blading material to a turbine unit of this type will make partial admission operation practicable. Blades fabricated of this material will withstand safely the added stresses imposed by blade loading and double shock, since, to avoid high shaft deflections, steam would be admitted to diametrically opposite nozzle quadrants.

The authors supplied considerable detailed information about the various turbine components. Provisions are made to periodically check the operation of all stop, interceptor and governing valves while the unit is carrying load. All "exercising" of these valves is accomplished from a central control test center. The operative position and function of these valves is traced and indicated by lights located on this test center. Safety in operation has been built into the test center which allows the operator to close only one stop valve and its companion steam flow control valve, one at a time, while all other valves are maintaining their normal operating functions.

New and additional duties are placed on the turbine control system by a boiler by-pass system arranged to

provide desired characteristics in cold starting, to permit quick hot restart of the steam generator, and to provide protection of the turbine unit under abnormal operating situations.

A review of the steam flow cycle, the authors stated, shows that steam from the steam generator has two routes to follow in reaching the condenser. When starting cold, circulation through the boiler is established by the motor driven boiler feed pump. This water must by-pass the turbine and be returned to the condensate system. Likewise, until uniform steaming at normal conditions is established, a by-pass for the steam must be provided around the turbine, through the reheater and to the condenser.

Water in the by-pass system is discharged from the by-pass separator through the water discharge valve to the condenser. Steam by-passes the turbine; first, through the by-pass separator; secondly, through the reheater; then to the condenser. Steam flow through the by-pass system is controlled by the automatic stop valve in the main header, the automatic superpressure by-pass valve at the main header, and the by-pass valve at the hot reheat line. Check valves in the cold reheat line and stop valves and interceptor valves in the hot reheat lines control steam flow from the by-pass system to the turbine. Motor operated by-pass valves are mounted at the check valves in the cold reheat lines for preheating.

The primary function of the automatic steam generator stop valves is their use during the startup period when water is pumped through the steam generator and superheater and through the by-pass system to the condenser. At this time, the valves are closed and prevent the flow of water into the turbine. When steam from the superheater is at the proper condition of temperature and pressure, the automatic control normally will open the valves. This opening can be prevented or limited to any desired amount by remote control. The valves may be cracked open just sufficient to preheat the main steam leads and then permitted to open as desired to bring the turbine into service. Under the influence of the automatic control, the valves will close automatically if pressure or temperature should fall below the set values. In normal operation, these stop valves are in the wide open position.

During operation, the superpressure by-pass valve acts as a safety device protecting the steam generator and the turbine against high pressure or temperature. If the steam pressure in the main header rises 5 per cent above normal, the by-pass valve will open. The valve is closed at any pressure below 105 per cent of normal. In this manner, the by-pass valve performs a function which is normally the duty of the power relief valve.

Protection for the turbine against excess temperature is desired. The superpressure by-pass valve is arranged to open automatically at a preset margin above normal temperature. Opening of the by-pass valve increases the steam flow and reduces the superheater outlet steam temperature. As soon as normal temperature conditions are re-established, the superpressure by-pass valve will close automatically.

The reheater by-pass valve permits steam flow through the reheater during start-ups and in case of emergency tripout of the turbine generator unit. The valve opens when the pressure in the reheater rises 5 per cent above normal, in response to an impulse from a pressure transmitter. The pressure setting of the transmitter is adjusted continuously with load in accordance with steam pressure in the turbine. If the pressure falls below the set value for any reason, the by-pass valve will close. During startup, it is expected that the set pressure of the by-pass valve will correspond to the pressure in the turbine when passing 30 per cent of maximum flow. Uniform steaming conditions will be established in the steam generator with a pressure at the reheater maintained at the 30 per cent flow pressure level.

In a similar vein the authors described the startup and normal loading procedures with some discussion of abnormal operating incidents.

Paradise Station

Reed A. Elliot, Walter F. Emmonds and **Henry T. Lofft,** Tennessee Valley Authority, described the "TVA's Paradise Steam Station Planning, Design, and Construction Highlights." The Paradise Steam Station is located in the south-central portion of the western Kentucky coal basin. Work started in the dust and mud of November 1959 and operation of the first 650-Mw unit is scheduled for September 1962. This unit will be followed by a second of equal capacity to be completed in July 1963. The station layout will accommodate two additional units of equal or greater capacity. Cost of the initial 2-unit installation is estimated at $182 million or $130 per kw, based on expected continuous capability.

In January of this year an all-time system peak load of 10,322 Mw occurred, at which time the assured load-carrying capacity of the system was 10,772 Mw. Upon completion of the Paradise units and installation of other additional hydro and steam units presently on order or under construction, the system capacity will reach 15,417 Mw by the fall of 1964. Projected load estimates indicate that this system will provide a margin of slightly under 10 per cent of dependable capacity above peak demand at that time. One Paradise 650-Mw unit at that time will represent approximately 4 per cent of the total system installed capacity.

Through the usual process of elimination by means of preliminary cost comparisons, the final choice of a site was reduced to two possibilities—the Hickory Point site on Kentucky Reservoir near the dam and the Paradise site. A detailed comparison of these two sites was made for an initial installation of one unit and for possible future installations of two, three and four units. For each case the plant investment at the site was found to be greater at the Paradise site by amounts ranging from about $1 million to nearly $3 million. These figures, however, do not reflect the prime advantage of a site located within an area of abundant coal resources. When the estimated savings in fuel costs at the Paradise site were included, the comparisons showed advantages to that site ranging from more than $1 million to nearly $5 million annually. Transmission costs were found also to favor the Paradise site and the choice was clearly apparent.

Under existing contracts for fuel supply, the bulk of the coal used for some time will be mined in the immediate vicinity of the plant and hauled over private roads to the plants. As necessary in the future, other facilities for fuel transportation can be provided.

River stages at the site can be expected in a range of 55 ft above the normal pool level of Green River Dam No. 2. The maximum flood of record (1937) rose some 50 ft above pool level. Taking into account the upstream flood control projects under construction by the U. S. Corps of Engineers, it is estimated that the maximum probable flood will reach a level 5 ft higher.

A considerable area of natural ground at the powerhouse site is at levels higher than the expected flood stages, but the greatest part of the site is low. Much of this low land will be used for ash disposal and brought up to levels suitable for coal storage. Fairly extensive areas must be filled, however, in the original construction.

The discharge of the Green River fluctuates widely under normal conditions. Extremes have been experienced from less than 500 cfs to about 205,000 cfs at the site in the 1937 flood. The upstream flood control reservoirs are planned to provide also a degree of low-flow regulation. With the operation as planned the discharge at the site will be greater than 1000 cfs about 95 per cent of the time. A 2-unit plant will operate satisfactorily on the river supply without supplementary cooling. In the event the station is expanded beyond two units, it is contemplated that artificial cooling facilities may be justified.

The presence of large reserves of strippable coal immediately adjoining a site suitable for a large-capacity generating station offered opportunities for exceptional economies both in the recovery and utilization of coal.

Coal delivered to the station, the bulk of it from the Kentucky No. 11 seem, will be somewhat lower in quality than that generally available to other TVA stations. It is expected that as-delivered thermal value will average slightly under 11,000 Btu, but because of the low production costs and the saving in transportation, the estimated cost of less than 14 cents per million Btu is unusually favorable.

With first-unit operation scheduled for September 1, 1962, approximately 30 months are allowed for completion of design and procurement. These schedules call for the making of approximately 3400 design drawings and preparation of procurement specifications for an estimated $117 million worth of major equipment and materials. The design work which is being done by TVA's Division of Design is estimated to cost $5 million or about 2.9 per cent of the estimated direct construction cost of the 2-unit plant. A consultant was employed to assist in the development of the principal architectural features and a scale model of the plant. At this time contracts have been placed for most of the major plant equipment, and design work is approximately 30 per cent complete.

Some of the design features which are different or unusual at Paradise from most other TVA steam plants are as follows:

1) Unprecedented size of generating units and related auxiliary equipment.

2) Service and office bay and turbine erection area in the center of an ultimate 4-unit plant with first two units on the river side; storage provisions in this structure allow elimination of separate yard storage buildings.

3) Four-unit electrical control wing adjacent to turbine erection area in central service bay. Two mechanical unit control rooms in bunker bay between boilers for 4-unit plant.

4) An underwater diversion dam in the river downstream from intake and combined skimmer wall and trash boom in intake channel.

5) Coal-handling system innovations for receipt of run-of-mine strip coal, including two 2000-ton ground level hoppers to accommodate 100- and 200-ton coal company trucks; 2000-ton-per-hr system for handling two grades of coal; two 100-ft-high live storage piles which permit reduction in capacity of boiler room coal bunkers to 13-hr. supply; four 600-ton-per-hr hammermill crushers; elimination of boiler room coal scales; and use of in-series belt weighing scales.

6) Cyclone fired boilers, tubular type air preheaters, and compressed air soot blowing.

7) No electrostatic precipitators or mechanical collectors for fly ash due to cyclone fired, slag-tap boilers and 600-ft-high chimneys.

8) Stored-program data processing-computing equipment with general-purpose digital computer for performance calculations, partial automation and monitoring, and expandable for possible complete automation.

9) Flash evaporator used for makeup and potable water supply, using raw river water from condenser water discharge; this allows elimination of conventional primary water-treatment plant at an approximate saving of $1.6 million.

10) Elimination of gantry crane for servicing pumps and traveling screens at pumping station and use of mobile yard crane; remote control of pumps from powerhouse unit control boards.

11) Station service of 6900 v with 6600-v motors for most of larger rated motors and 480-v service for smaller 440-v motors.

12) Elimination of central vacuum cleaning plant and use of industrial-type vacuum cleaning equipment.

ISA Power Symposium

The Fourth National ISA Power Instrumentation Symposium, May 8–10, LaSalle Hotel, Chicago, sponsored by the Instrument Society of America will present papers by key personnel from Carolina Power & Light Company, Commonwealth Edison Company of Chicago, Detroit Edison Company, Duquesne Light Company of Pittsburgh, Gulf States Utilities Company, Philadelphia Electric Company, Public Service Company of New Hampshire, Texas Electric Company, and Texas Power & Light Company.

"Data Logging Development & Computer Experiences in Eight Installations of Gulf States Utilities Company" by J. O. Robichau, "Putting the Digital Computer to Work at the H. B. Robinson Station" by H. Wachtel of Ebasco Services, Inc., and "The Semi-Automatic Station Evolves" by R. F. Scheibel of Sargent & Lundy will make up a featured session on computer experience.

Editor's Note: On pages 17 and 18 we have inserted a post card on which we ask you to give us your reactions to the articles in this magazine. Will you please help us by checking off the card and returning to us?

Abstracts from the Technical Press—Abroad and Domestic

(Drawn from the Monthly Technical Bulletin, International Combustion, Ltd., London, W. C. 1)

Fuels: Sources, Properties and Preparation

Coal Derivatives. Anon. *Coke and Gas* **1960, 22** (*Oct.*), 421–5, 448.

The "Wilson" report of the Committee on Coal Derivatives" (Cmd. 1120) is analysed in detail and discusses the following sections: (1) Coal carbonization and the gas industry; (2) developments in complete gasification; (3) industrial gas; (4) synthesis of oil from coal; (5) coal as a chemical raw material; (6) general conclusions.

Gravimetric and Volumetric Measurements During the Degasification of Coals. H. Luther, O. Abel, A. Kett and K. C. Traenckner. *Brennst-Chemie* 1960, **41** (Sept.), 257–63 (in German).

The investigations into degasification of coals and their softening and their mutual relationship were carried out by measurements of the degasification rate as a function of mechanical (bulk density, particle size distribution), physical (pressure, rate of heating) and chemical (preoxidation, alien gasses) factors. Discrete ranges of decomposition were found which show the presence of chemical groups with certain dissociation energies; the analysis of the decomposition products confirmed this. The properties of coking coals depending mainly on the extent of release of liquid products between 350 and 400 C and of methane between 450 and 500 C.

Mechanical Handling

Grading Coal and Dirt at Lea Hall Pit. Anon. *Engineering* 1960, **190** (Sept. 23), 420–1.

The power station under construction near Lea Hall Colliery with a total capacity of 600 Mw is exclusively supplied by conveyor direct from the colliery which sorts and washes coal and dirt from its own production and from several other mines in the district. The coal and dirt handling, sorting and washing plant is described.

Handling Lump Coal on Belts. D. C. Jones. *Mechanisation* 1960, **24** (Sept.) 73–5.

An installation able to transport up to 12,000 t per shift of large coal from a mine to the wagon loading point is described. Ropeside frame belt conveyors were chosen because they can easily be extended or contracted and the cushioning effect when transporting large lumps.

Automatic Coal Transfer from Wagon to Ship. Anon. *Engineering* 1960, **190** (Oct. 7), 485.

Two identical plants have been installed at Immingham for the unloading of wagons into ships. Each can handle 55 wagons of 10 to 24.5 ton capacity and consists of a combination of wagon haulage and tippling plant connected by a belt conveyor to a loading tower with adjustable boom for discharge into the ship's hold. The installations operate automatically and each requires only 2 men for supervision.

The Transport of Pulverised Coal by Carrier Gas in Pipe Lines and its Influence on the Control of the Combustion Conditions. A. Schneider. *Energie* 1960, **12** (Sept.), 378–88 (in German).

Starting from the movement of a single particle and a particle mixture the flow in a pipe upwards or downwards, horizontally and in bends has been studied and equations for calculating the transport time have been deduced. Recommendations are made with regard to the planning and design of pipe lines and, especially of the bends, to reduce the total transport time. The influence of the transport time on the control of the combustion conditions is discussed and illustrated by an example.

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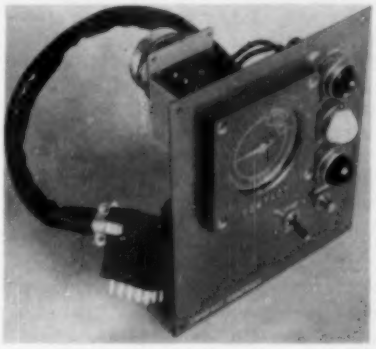

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Steam Generation and Power Production

Tests on the Thermal Conductivity of Water Vapor. H. B. Vargaftik and A. A. Tarzimanov. *Teploenergetika* 1960, **7** (July), 12–16 (in Russian).

The results are given of tests on the thermal conductivity of water vapour in the temperature range of 600F to 1040F and pressures from 70 psig to 7100 psig. *C.E.G.B. abstract.*

Design and Construction of Pressure Vessels. J. J. Haftke. *Chem. Proc. Engng* 1960, **41** (Oct.), 437–44.

The factors to be considered in designing a pressure vessel for a nuclear reactor are discussed: (1) fatigue; (2) excessive deformation; (3) corrosion; (4) brittle fracture; (5) creep rupture. Also discussed are accuracy limitations, economy, speed of construction, radiation effects and constructional considerations.

Design of Reinforced Cylinder for Nuclear Reactor Pressure Vessel. R. W. Lakin and S. S. Gill. *Engineer* 1960, **210** (Sept. 23), 495–9.

The reinforcement consists of layers of thin plate around the main cylinder, the joints being welded. This permits the use of higher pressures and greater heat production without proportionate increase in costs. The design is described and results of tests on two 1/10th models presented.

Hydrodynamics of Forced Circulation Boilers. A. A. Davidov and B. I. Sheinin. *Teploenergetika* 1959 (Nov.), 53–7. D.S.I.R. *Transl. RTS* 1584.

Data on the resistance of tubes in the water and steam circuit, pulsation in tubes, differences of temperature between tubes and header, distribution of the steam-water mixture and its stratification is forced circulation boilers.

Boiler Design for Low Grade Coal in Power Plants. B. Limpouch. *Technical Digest* (Czech) 1960, **2** (Mar.), 43–6.

Czechoslovakia's extensive experience in the field of steam-boilers for high-moisture fuels and ash contents of up to 60 per cent is illustrated with the numerous design examples described. Lignites and brown coals as well as high-ash black coals are

PATHWAYS OF A PIONEER

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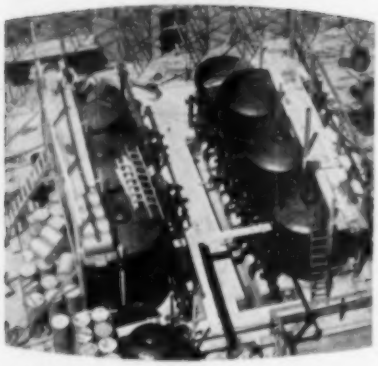

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burnt successfully. Good results have been obtained with stoker-fired and particularly with pulverized-fuel fired boilers. Both dry-bottom and slag-tap boilers are used and boilers fitted with double-pass combustion chamber developed in Czechoslovakia have proved most successful and versatile as regards both fuel composition and ash properties.

From C.E.G.B. Digest 1960, **12** (Sept. 24), 2573.

Furnaces and Combustion

Control of Reaction Rate in Dust Flames. J. M. Beer and R. H. Essenhigh. *Nature* 1960, **187** (Sept. 24), 1106–7.

Recent investigations on pulverized anthracite flames tend to show that a chemical rate control is important in the combustion process and the previous theory of diffusional control is not valid.

Water-Side Corrosion and Water Treatment

Water-treatment with Hydrazine for Protecting Boiler Metal against Corrosion. P. A. Akolzin and N. M. Mikailova. *Teploenergetika* 1960, **7** (July), 59–64 (*in Russian*).

The results are described of an investigation on the development of the use of hydrazine in the treatment of boiler water to protect boiler metal against corrosion.

C.E.G.B. abstract.

Laboratory Investigation of Water-Side Scale and Corrosion in the Presence of High Process-Side Temperatures. H. Kerst. *Corrosion* 1960, **16** (Oct.), 131–7.

The tests were carried out with 130 F water and 350–395 F hotside temperature to investigate corrosion and calcium phosphate scale deposition. Use of polyphosphates at residual levels high enough to give corrosion protection produces calcium phosphate scale. Chromates reduce the amount of this scale and also carbonate scale.

Gas-Side Corrosion and Deposits

Some Properties of Ash Deposits Accumulated on the Screen Tubes of Boiler Furnaces. A. M. Gurvich and R. S. Prasolov. *Teploenergetika* 1960, **7** (July), 80–6 (*in Russian*).

Measurements were made on the thickness of the layer and weight of ash deposits on boiler screen tubes. The growth of deposits over time and their effect of heat transfer in the furnace were determined. It was found that in some definite cases the thermal conductivity of the initial layer of deposit may be lower than that of air.

C.E.G.B. abstract.

Linden Combats Boiler Tube Corrosion with $Mg(OH)_2$. R. A. Baker. *Pwr Engng* 1960, **64** (Sept.), 58–9.

The oil used at this power station contains between 100 and 500 ppm vanadium, on average 350–400 ppm and this in conjunction with sodium and sulfur caused severe, very sticky and corrosive deposits in the boilers. After tests it was decided to use magnesium hydroxide in preference to the oxide which tends to take up moisture and clog pipelines and nozzles. The $Mg(OH)_2$ is injected into the furnace just above the burners at a ratio of 2 parts to 1 part vanadium. The magnesium is ground to 90 per cent through 325 mesh and maximum consumption is 160 lb/h per furnace. The deposits though increased in amount are now dry and fluffy and easily removed by soot blowing. Corrosion of the air heater has not been reduced and they are washed every 3 months.

Corrosion of Steel in Hot Gases. H. Keller. *Chem. Ing. Tech.* 1960, **33** (Sept.), 582–4 (*in German*).

Corrosion of ferritic steels by sulfur and vanadium pentoxide is discussed and results of tests of the corrosion resistance of various ferritic chromium steels presented. It is shown that in many cases these steels are superior to austenitic steels though their heat resistance is lower.

Flue Gas, Ash and Dust

Recommendations on Heights for New Industrial Chimneys. G. Nonhebel. *J. Inst. Fuel* 1960, **33** (Oct.) 479–511.

It is recommended that: (1) Chimneys for large plants be so high that the calculated 3 min-max concentration of SO_2 at ground level does not exceed 40 pphm (by vol) in areas of heavy industry or high density of population and 50 pphm in other areas and the maximum rate of deposit of grit and dust not exceeding 1000g/100 m² month with a wind direction constant within an octant; (2) A sliding scale of chimney heights from 60 to 120 ft for boiler plants from 5000 to 33,000 lb/h. Rate of dust deposition will generally control the chimney height and not the SO_2 concentration. It is important that particles larger than 76 μ should not be emitted from chimneys. Recommendations are also made on the design of chimneys (combination of flue gases in one or two chimneys, avoidance of down draught and downwash). The first appendix deals with the methods of calculating chimney

height and the second appendix with a formula for threshold visibility of a dusty plume.

The Selection of Optimum Temperatures for Boiler Flue Gases. M. A. Styrikovich, G. A. Matveev and V. I. Belyaev. *Teploenergetika* 1960, **7** (July), 27–32 (*in Russian*).

The optimum temperatures of flue gases are determined from the technical and economic aspects, for high-capacity boilers operating on coals of different prices.

C.E.G.B. abstract.

An X-ray Study of Pulverized Fuel Ash. H. S. Simons and J. W. Jeffrey. *Appl. Chem. J.* 1960, **10** (Aug.), 328–36.

Pulverized fuel ash has been subjected to X-ray examination and chemical analysis and the main mineralogical and physical characteristics have been determined. It is shown that the ash is a very complex material in which the overall chemical composition varies from particle to particle. It is tentatively concluded that there is a positive correlation between pozzolanic activity and glass content. The types of combination of iron present in the ash have been determined and the effect of hydration examined.

From C.E.G.B. Digest 1960, **12** (Sept. 24), 2577.

Heat Recovery Plant

Plate Heat Exchangers. Flow Characteristics. E. L. Watson, A. A. McKillop, W. L. Dunkle and R. L. Perry. *Ind. Engng Chem.* 1960, **52** (Sept.), 733–40.

A study of velocity patterns, residence times and pressure drop has been carried out to assist in design and use. The results are presented in graphs.

Plate Heat Exchangers. Heat Transfer. A. A. McKillop and W. L. Dunkley. *Ind. Engng Chem.* 1960, **52** (Sept.), 740–4.

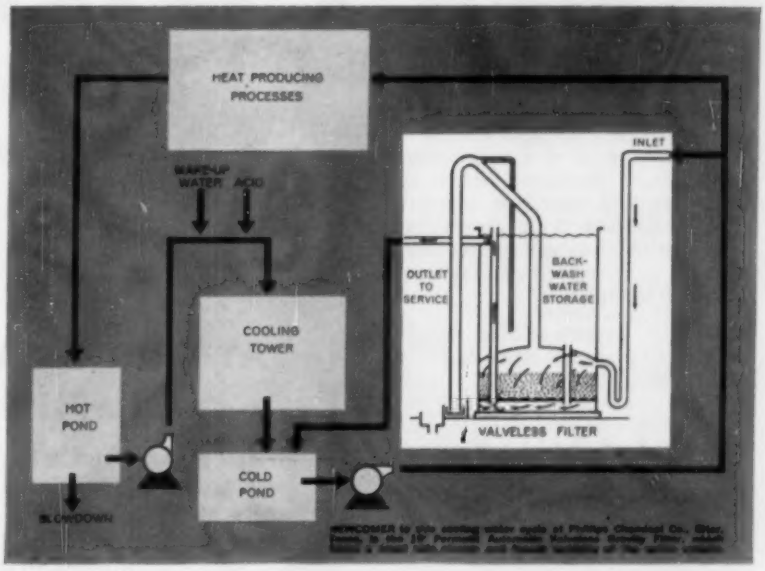
A theoretical and experimental study showing that turbulence promotors and flexible plate arrangements result in high rates of heat transfer and low pressure drop.

Power Generation and Power Plant

A Look at Big-Power Cycles for 40 per cent Thermal Efficiency or Better. P. H. Knowlton. *Steam Engr.* 1960, **30** (Oct.), 16–21.

Various ways are considered in which the thermal efficiency of power generation could be increased. Improvement in the steam cycle, application of the binary cycle, superposition of the gas turbine cycle

FLUIDICS* AT WORK



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over the steam cycle, gas turbine cycles alone and fuel cells are discussed. Which of these would constitute the best approach to high efficiencies is left open.

Off-Load Efficiency for Boilers. Gas-Tight Sealing of Plant Provides Many Economies. P. E. Jents. *Fuel Effic.* 1960, **8** (Oct.), 59–60.

Tight sealing off of a boiler plant during longer shutdown periods or during low-load operation together with intermittent firing greatly increases the efficiency and reduces smut or smoke emission. This also reduces the danger of corrosion.

Steam for Japan's Chiba Power Station.z J. Grindrod. *Steam Engineer* 1960, **30** (Oct.), 22-3.

This station contains two 125 and two 175 Mw units with a total consumption of coal of 1,650,000 t. No. 1 boiler by C.E. is rated at 960 klb/h at 1825 psi and 1005/1005 F; No. 2 boiler is a Japanese copy of No. 1 but for a pressure of 1880 psi; No. 3 boiler by Babcock and Wilcox is rated at 1300 klb/h at 2467 psi and 1060/1010 F; No. 4 boiler is identical with No. 3 but made by Babcock Hitachi.

The Elektrim (Warsaw) 360 Mw Steam Power Station: First (220 Mw) Stage. H. Scheidt. *Siemens Zeits.* 1960, **34** (July), 410–421 (*in German*).

The station, one of the most economical in Poland, has four 55 Mw sets in the first stage of construction and two 70 Mw reheat sets in the second, with natural-circulation and Benson boilers respectively; these will be pf fired.

From C.E.G.B. Digest 1960, **12** (Sept. 24), 2563.

Kincardine Power Station. Anon. *Elect. Times* 1960, **138** (Oct. 13), 565–7.

Kincardine power station, officially opened on Oct. 12, 1960, now has three 120 Mw sets in operation and two 200 Mw sets under construction to provide a total capacity of 700 Mw. The three boilers in operation (1 by International Combustion, 2 by John Brown Land Boilers Ltd) are each rated at 860 klb/h and 1010/1005 F. The first boiler is provided with 5 roller-type pulverizers (1 reserve) and four tilting burners in each corner, spray-type desuperheater for the superheated steam and burner tilt control for the reheated steam. The second and third boilers are each provided with four high-speed attrition pulverizers (1 reserve), 16 burners in the front wall, spray desuperheaters for the superheated steam and control of gas flow over

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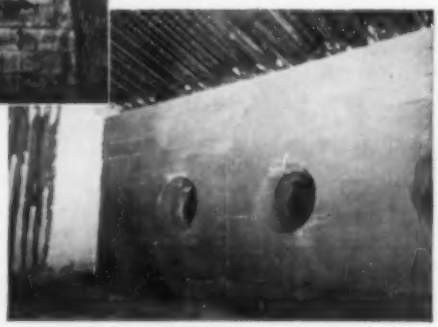

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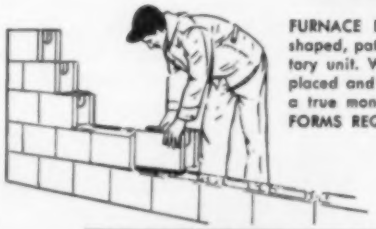

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Ruien Steam Power Station, Belgium. P. Barbey and F. Bachmayer. *Sulzer Tech. Rev.* 1960, **42** No. 1, 13–21.

This power station contains two 60 Mw units each served by a Sulzer monotube boiler rated at 408 klb/h, 2060 psi and 1015/1015 F. The reheating of the steam is based on the Triflux system and the reheated steam temperature is held constant down to 30 per cent of full load. Boiler thermal efficiency on nett C.V. of the fuel is 90.3 per cent at 20 Mw (⅓ load) and 92 per cent at full load; overall net thermal efficiency of the station is over 37 per cent.

The La Spezia Thermal Power Station of Edisonvolta. Anon. *Quaderni* 1960, **16** (July 16), 553–61 (in Italian).

The projected station will have one 320 Mw unit which will be the largest unit installed or being installed on the continent. Steam will be generated in the boiler, designed by Combustion Engineering, at 2520 psig, 1050 F, with reheat to 1000 F. The 3000 rpm. Tosi-Westinghouse turbine will drive two 170 MVA hydrogen-cooled alternators manufactured by Marelli under Westinghouse licence.

From C.E.G.B. Digest 1960, **12** (Sept. 24), 2561.

Steglitz Gas Turbine Power Station in Operation. Anon. *Energie* 1960, **12** (Sept.), 377 (in German).

This power station contains 2 gas turbines each generating 25 Mw to provide peak load in the morning and evening and in emergencies. One part of the gas turbine drives the hp compressor, the other the lp compressor and generator. The thermal efficiency is 25.7 per cent.

Dresden Nuclear Power Station. Various Authors. *Nucl. Engng* 1960, **5** (Oct.), 434–41.

(1) Outline design; (2) design philosophy by V. D. Nixon; (3) safety aspects by V. D. Nixon; (4) full power operation.

N.S. Savannah. Various Authors. *Nucl. Engng* 1960, **5** (Oct.), 447–9.

(1) General description; (2) control rod operation; (3) refueling by by J. D. McDaniels.

Yankee Atomic Electric. Various Authors. *Nucl. Engng* 1960, **5** (Oct.), 466–76.

(1) General description by J. N. Kilpatrick; (2) reactor vessel by P. B. Haga; (3) initial core by A. G. Thorp; (4) control rod drive mechanism by T. F. Widmer; (5) reactor control system by C. F. Obermesser; (6) fuel handling by H. A. Smith.

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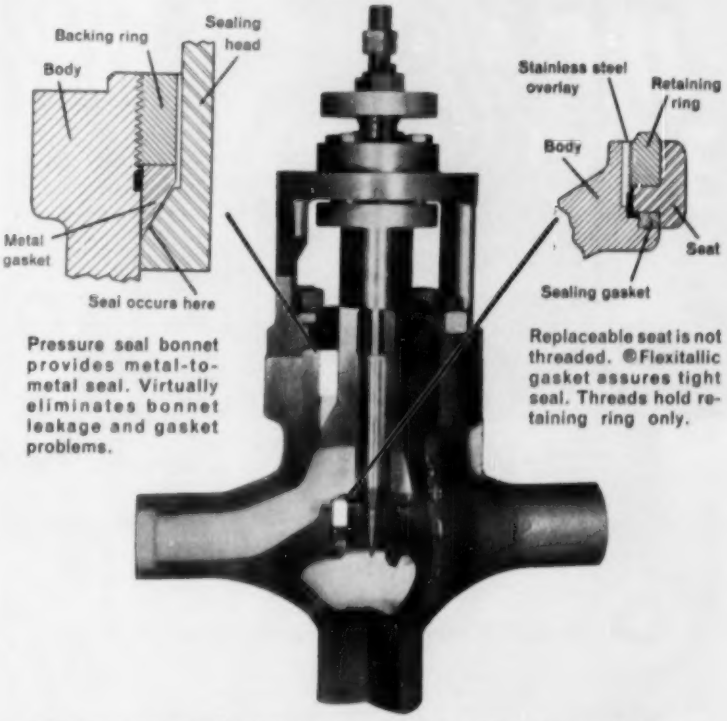

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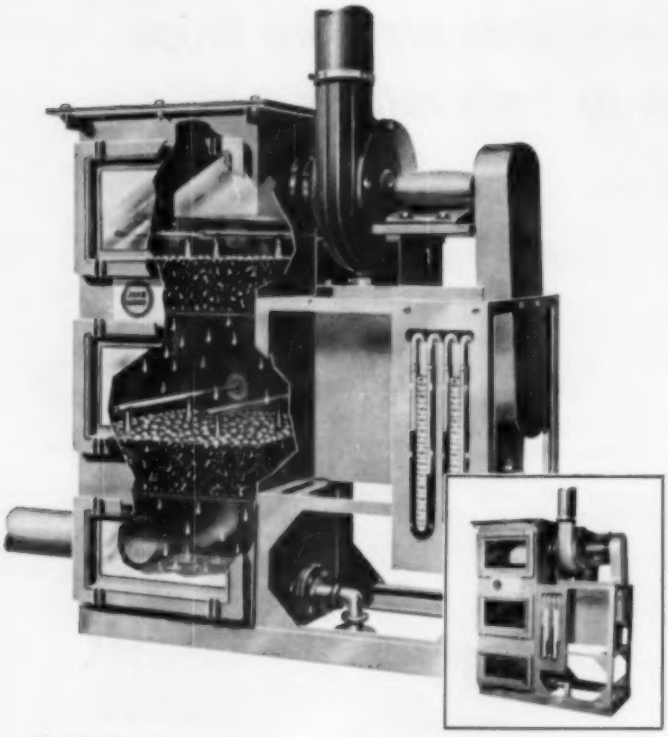

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Advertisers' Index

Aerotec Industries, Inc. ..... *
Air Preheater Corporation, The 5
Anaconda American Brass Company 66

Bailey Meter Company . 42 and 43
Bayer Company, The 10
Bell & Zoller Coal Company ... *
Bird-Archer Company ..... *
Buell Engineering Company, Inc. 20
Buffalo Forge Company 3

Cambridge Instrument Company ..... *
Clarage Fan Company ..... *
Coen Company ..... *
Combustion Engineering, Inc. ..... Second Cover, 8 and 9
Combustion Publishing Company, Inc. ..... 17 and 18
Compact Controls Company, Inc. 59
Copes-Vulcan Div., Blaw-Knox Company ..... 6 and 7

Dearborn Chemical Company . 13
De Laval Steam Turbine Company ..... *
Diamond Power Specialty Corporation ..... *
Dow Industrial Service, Div. of The Dow Chemical Company ..... Fourth Cover

Eastern Gas & Fuel Associates *
Edward Valves, Inc. ..... 14 and 15

Fairmount Chemical Company *
Foxboro Company, The ..... *

Garden City Fan & Blower Co. ..... *
Grinnell Company 12

Hagan Chemicals & Controls, Inc. ..... *
Haskins Turner Company ..... *

(Continued on page 65)

Illinois Water Treatment Co... 60

Johns Manville.....48 and 49

M. W. Kellogg Company, The .....28 and 29
Koppers Co..... *

Manning, Maxwell & Moore, Inc..... *
W. K. Mitchell & Company.. 4

Nalco Chemical Company.... *

Ontario Hydro 47

Peabody Engineering Corporation..... *
Pennsylvania Crusher Div., Bath Iron Works Corp..... *
Pfaudler Permutit Inc..... 61
Powell Valves..... 30

Refractory & Insulation Corporation..... 62
Reliance Gauge Column Company, The..... 16
Republic Flow Meters Company..... 63
Republic Steel Corporation... *
Research-Cottrell, Inc...Third Cover
Richardson Scale Company... 65
Rohm & Haas Company..... *

Stock Equipment Company... *
Sumco Engineering, Inc..... *

Todd Shipyards Corp., Products Div..... *

Valley Camp Coal Company.. 19

John Wood Company..... 64
Worthington Corp..... *

Yarnall-Waring Company.... 11
Yuba Consolidated Industries, Inc..... 2

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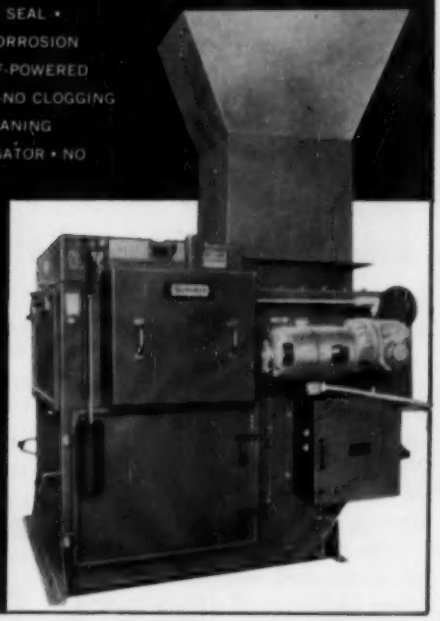

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200	17,500
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350	16,400
400	16,100
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550	15,400
600	15,200

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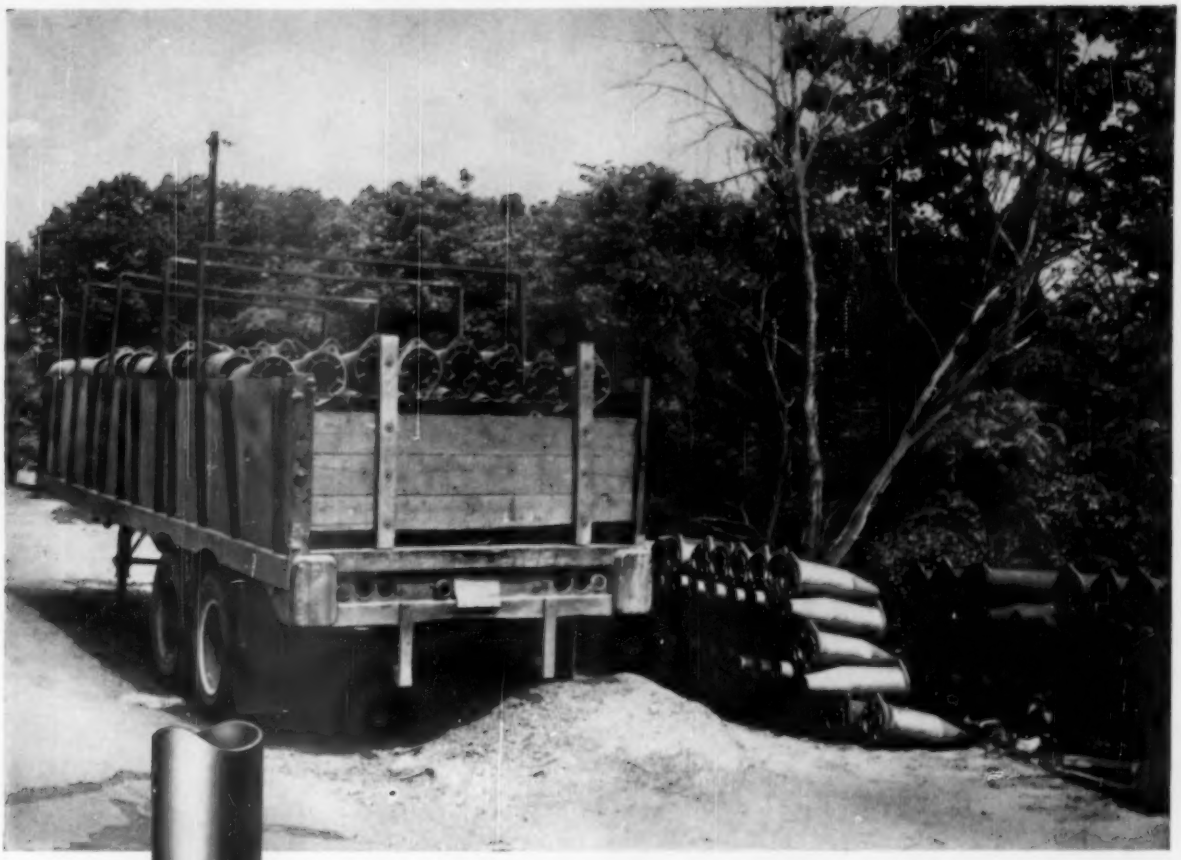

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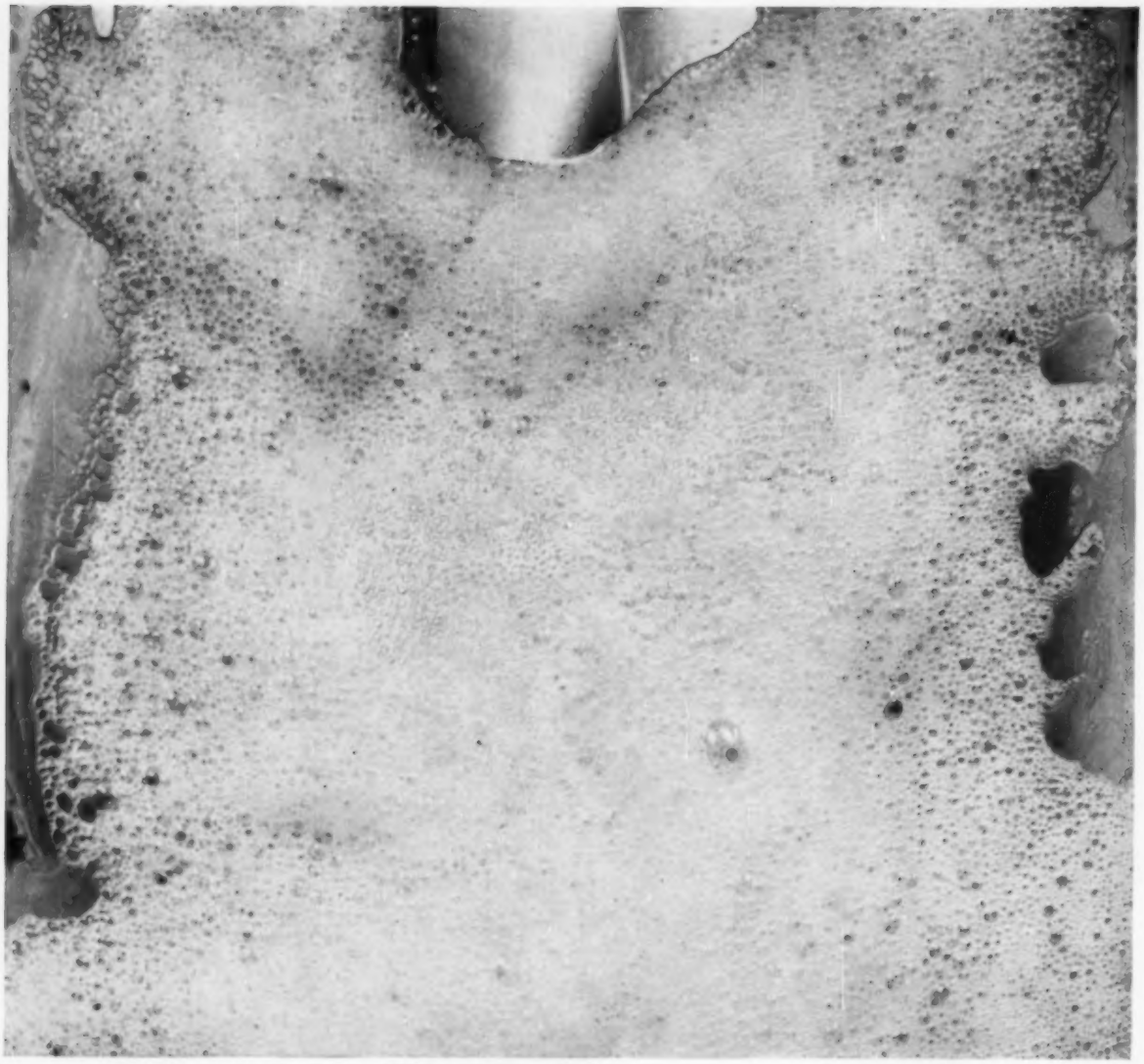

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